Original Article

# Evaluation of age-based local anaesthetic dosing of bupivacaine for popliteal sciatic nerve block in children undergoing foot and ankle surgery: A prospective single arm interventional study

**Address for correspondence:**
Dr. Balachandar Saravanan, Department of Anaesthesiology, Jawaharlal Institute of Postgraduate Medical Education and Research, Karaikal, Puducherry, India.
E-mail: amuchandru@ymail.com

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*Srinivasan Parthasarathy, T. Kumar Venkatesh, Balachandar Saravanan[1]*

**Department of Anaesthesiology, Mahatma Gandhi Medical College and Research Institute, Sri Balaji Vidyapeeth, Pillayarkuppam, Pondicherry, [1]Department of Anaesthesiology, Jawaharlal Institute of Postgraduate Medical Education and Research, Karaikal, Pondicherry, India**

## ABSTRACT

**Background and Aims:** Recommendations on paediatric single-injection local anaesthetic (LA) dosing for peripheral nerve blocks (PNBs) are based on the children's weight and limited by weight-based toxicity concerns. In this study, we assessed the extent of circumferential spread and block characteristics following the injection of an age-based volume (age in years = LA volume) of 0.25% bupivacaine following popliteal sciatic nerve block (PSNB). **Methods:** Thirty children aged between 2 and 12 years with the American Society of Anesthesiologists (ASA) physical status I and II and undergoing foot and ankle surgical procedures were given single-injection ultrasound-guided subparaneural PSNB using 0.25% bupivacaine at age-based LA volume after the administration of anaesthesia. The circumferential pattern of LA spread (primary objective) was assessed along the nerve (both cephalad and caudal) using ultrasound from the point of administration and the block characteristics in terms of duration of sensory block. **Results:** The mean [standard deviation (SD)] cephalic circumferential LA spread distance was 2.52 (0.68) [95% confidence interval (CI): 2.27–2.76] cm. The mean (SD) caudal circumferential LA spread distance was 2.27 (0.48) [95% CI: 2.09–2.44] cm. The mean (SD) duration of the sensory block was 9.03 (0.97) [95% CI: 8.67–9.38] h. **Conclusion:** The age-based LA volume of bupivacaine for ultrasound-guided PSNB resulted in a longitudinal circumferential spread of around 4.7 cm (adding both cephalic and caudal spread) and provided adequate analgesia for nine postoperative hours.

**Keywords:** Analgesia, bupivacaine, dosing, paediatric, peripheral nerve block, popliteal sciatic nerve block, ultrasound

## INTRODUCTION

The advent of paediatric regional anaesthesia in multiple surgical disciplines has proven reliable in providing perioperative analgesia and reducing opioid utilisation.[1] The presence of target neural structures close to vascular structures, the pre-requisite for sedation or general anaesthesia that masks potential warning signs like paraesthesia and the need to limit the local anaesthetic (LA) volume below toxic levels are considered the potential challenging factors of regional anaesthesia techniques in children.[2] However, large LA doses for peripheral nerve blocks (PNBs) are documented in adults and paediatric age groups.[3] Recent evidence from the Pediatric Regional Anesthesia Network (PRAN) has documented variation in LA dose for the ten most commonly administered paediatric PNBs and found excess dosing from the average LA



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dose per kilogram among 80% of all doses given.[4] The European Society of Regional Anaesthesia and Pain Therapy (ESRA)/American Society of Regional Anesthesia and Pain Medicine (ASRA) Joint Committee practice advisory has recommended a single injection dose of bupivacaine, levobupivacaine or ropivacaine for ultrasound-guided upper and lower extremity PNBs in children as 0.5–1.5 mg/kg.[5] However, the level of evidence was based on observational studies with associative statistics, and weight-based toxicity concerns in children limit most block dosages. Hence, there is a possibility of increased risks of LA systemic toxicity with weight-based dosing, which can be further exaggerated with varying body weight among children of the same age, especially with increasing childhood obesity.[6,7]

Therefore, we formulated the single-injection LA volume for 0.25% bupivacaine based on the patient's age (age in years = LA volume) for popliteal sciatic nerve block (PSNB). The aim was to determine its effect on the extent of LA spread along the nerve and the block characteristics. The primary objective was to determine the length of the circumferential pattern of LA spread along the nerve (both cephalad and caudal) from the point of injection in PSNB. The secondary objective was to determine the duration of the sensory blockade.

## METHODS

The Institutional Research and Human Ethics Committee approved this prospective observational study (vide approval number No. MGMCRI/Res/01/2020/90/IHEC/330 dated 16 March 2021), and the study was registered with the Clinical Trials Registry – India (vide registration number CTRI/2021/11/037923, www.ctri.nic.in/). The study was conducted from May 2021 to August 2022 at a tertiary academic hospital. It was carried out as per the principles of the Declaration of Helsinki, 2013. Children aged 2–12 years belonging to the American Society of Anesthesiologists (ASA) physical status I/II and undergoing foot and/or ankle surgical procedures were included in the study by continuous sampling method. Patients with known allergies to LA solution, bleeding disorder, liver failure, vascular injury, distal lower limb vascular procedures, paralysed limbs or difficult sonoanatomy identified during scout scanning were excluded. After obtaining written informed consent from the parents for participation in the study and using the patient data for research and educational purposes, the children were kept nil per oral for 2 h for clear fluids and 6 h for milk or semi-solid or solid foods. Syrup promethazine 0.5 mg/kg per oral was given as premedication the night before and in the morning 2 h before surgery. Following the premedication in the morning, they were allowed to sleep in the preoperative holding room with parental support and shifted to the operating room.

In the operating room, general anaesthesia (technique at the discretion of the attending anaesthesiologists) was administered after attaching standard monitors and securing peripheral venous access. The anaesthesiologist with substantial expertise (>1-year experience in paediatric ultrasound-guided PNBs) performed the ultrasound-guided PSNB under strict aseptic precaution using a high-frequency linear array transducer (HFL 15-6 MHz, X-Porte, FUJIFILM Sonosite, Inc, Bothell, WA, USA). With the patient in prone position, the probe was placed over the popliteal fossa to identify the tibial nerve (around the popliteal vessels). Subsequently, the nerve was followed rostrally until it merged with the common peroneal nerve (identified as neural bifurcation, where both branches are situated contiguously, giving a bilobular pattern) [Figure 1]. Using an out-of-plane technique, a 23G Quincke spinal needle was advanced until its tip was positioned between the tibial and peroneal nerves inside the paraneural sheath and a small volume of saline (0.2 ml) was injected to obtain a circular expansion of the paraneural sheath further to ensure the needle tip position. After that, age-based LA volume (determined as a volume in 'ml' corresponding to the age of the children in years) of the drug 0.25% bupivacaine was administered. After

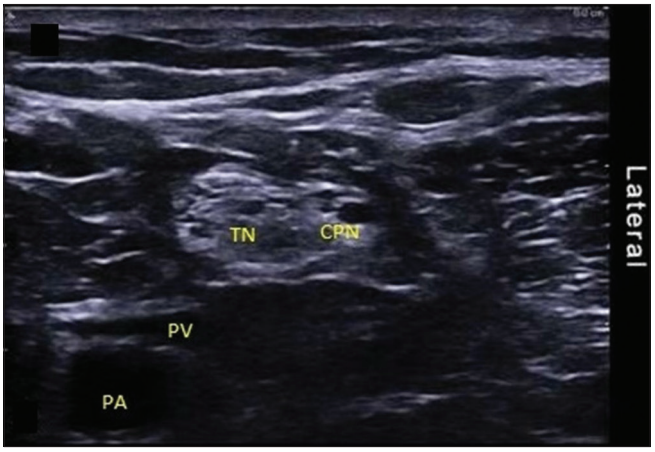


**Figure 1:** Ultrasound image of the bilobular pattern popliteal sciatic nerve at the level of nerve bifurcation. CPN = common peroneal nerve, PA = popliteal artery, PV = popliteal vein, TN = tibial nerve

completing the block, the circumferential drug spread in a short axis was assessed along the nerve using ultrasound (both cephalad and caudal) from the point of administration. The distance on either side from the point of administration was measured using a sterile stainless steel ruler and documented. In cases where the distal spread involved both tibial and peroneal nerves, the drug spread length along the individual nerves was measured, and an average was taken. A cephalo-caudal circumferential drug spread of 1 cm from the point of administration was considered successful as clinical assessment could not be done in a patient under anaesthesia. In the postoperative period, the sensory block assessment was done by a blinded observer using a pinprick and cold swab technique in the common peroneal and tibial nerve territories of the foot (both plantar and dorsal sides). The sensory block assessment was done every 30 min after surgery. The duration of the sensory block was defined as the time taken to perceive pinprick from the time the block was administered. The attending anaesthesiologist decided on postoperative pain management and monitored for complications.

In this pilot trial, the minimal sample size requirement was calculated based on the rule-of-thumb method proposed by Browne. According to this simple rule, a minimum sample size of 30 was appropriate for estimating a parameter.[8] Statistical calculation was done using Statistical Package for the Social Sciences (SPSS) version 20.0 (International Business Machines Corp, Armonk, NY, USA). Continuous data such as surgery duration, duration of sensory block and cephalic and caudal circumferential LA spread distance were presented as mean and standard deviation (SD). Categorical data such as gender was presented as numbers. Continuous data with skewed distribution, such as age, height, weight and body mass index (BMI), were presented as the median and interquartile range (IQR). Descriptive statistics were used in the study [estimation of mean (SD) and median (IQR)].

## RESULTS

Thirty-five patients were assessed for eligibility, of which 30 met the inclusion criteria and were included in the study. Five were not enroled, as parental consent could not be obtained. Patient characteristics and duration of surgery are presented in Table 1. The mean (SD) cephalic circumferential LA spread distance was 2.52 (0.68) cm [95% confidence interval (CI): 2.27–2.76]. The mean (SD) caudal circumferential LA spread distance was 2.27 (0.48) cm [95% CI: 2.09–2.44]. The mean (SD) duration of the sensory block was 9.03 (0.97) [95% CI: 8.67–9.38] h. None of the patients developed injection site haematoma, local site infection, persistent new paraesthesia or weakness in the lower limb after the procedure.

**Table 1: Patients' demographic data**

| Variables | Findings |
|---|---|
| Age (years) | 7 (4–10) |
| Gender (male/female) | 22/8 |
| Height (cm) | 121 (100–130) |
| Weight (kg) | 22 (17.75–25.25) |
| Body mass index (kg/m$^2$) | 16.8 (15.2–20.8) |
| Surgery duration (min) | 88.3 (18.2) |

Data are expressed as mean (standard deviation), median (interquartile range) or number

## DISCUSSION

In this study, the age-based LA volume of 0.25% bupivacaine for ultrasound-guided PSNB was sufficient to produce a circumferential pattern of LA spread around PSNB and a soak of around 4.79 cm along the nerve.

In our hypothesis, the cephalic and caudal spread length of >1 cm on either side was considered sufficient for the block effect based on the conclusions described in textbooks that a soakage of a maximum of 4 mm in nerves will provide an adequate block effect.[9] Hence, in our study, we kept a soakage length of 1 cm on each side to project as a successful block. We achieved this in all the cases. As the soakage was more than 4 cm, we could not substantiate that 2 cm is enough. Still, an age-based formula effectively gives clinically relevant analgesia. Literature on the effective length of LA spread along the nerve, especially in children, is sparse. The mean length of the longitudinal perineural spread of LA in the ultrasound-guided subfascial popliteal sciatic nerve in adults was 66% more than the conventional extrafascial PSNB (9.3 vs. 5.6 cm).[10] However, no such information is available for children. This is the first study to obtain a mean length of longitudinal perineural LA spread along the popliteal sciatic nerve in children. Due to a wide dose range, the weight-based LA dose calculation may need to be more convenient in clinical settings. Determining the dosage in individual cases with wide and polar weight differences can be challenging. Therefore, an effort was made to ascertain the age-based LA volume calculated in this study, and it was found to be well

within the maximum LA volume calculated based on a validated normogram.[11] The maximum LA volume for 0.25% bupivacaine calculated based on a nomogram was 50% more than the total LA volume calculated based on age. Similarly, the age-based dosing of 0.5% hyperbaric bupivacaine for spinal anaesthesia in children provided adequate surgical anaesthesia at volumes lesser than the conventional weight-based dose calculation.[12]

It is evident from the literature that the circumferential pattern LA spread and separation of the nerve into two components is associated with a higher block success rate and rapid onset than the non-circumferential LA spread in adults.[13] Also, the circumferential LA spread pattern may be more relevant in determining the block success with large nerves like the popliteal sciatic nerve.[14] Similar to our finding, PSNB has been found to provide adequate analgesia during the first 8–12 postoperative hours without the need for rescue analgesics following foot and ankle surgery in children.[15]

The present study findings might not be extrapolated to other peripheral nerves and for using different LA concentrations. In addition, the sample size included in this study was calculated for a pilot study. Therefore, the outcomes presented in this study need further validation with randomised clinical trials with an appropriate sample size. Secondly, the utility of the circumferential pattern of LA spread and longitudinal spread length of more than 2 cm in determining the success rate of PNB applies to the popliteal sciatic nerve. It may be used as a guide in future for other peripheral nerves. Future research focus might be a randomised trial between age- and weight-based dosing.

## CONCLUSION

The age-based LA volume of bupivacaine for ultrasound-guided PSNB resulted in a longitudinal circumferential spread of around 4.7 cm (adding both cephalic and caudal spread) with adequate postoperative analgesia.

### Study data availability

De-identified data may be requested with reasonable justification from the authors (email to the corresponding author) and shall be shared after approval as per the authors' institution policy.

### Financial support and sponsorship

Nil.

### Conflicts of interest

There are no conflicts of interest.

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