Minimum effective anesthetic concentration (MEAC) for sciatic nerve block: subgluteus and popliteal approaches

[Concentration anesthésique efficace minimale (CAEM) pour un bloc du nerf sciatique : approches sous-glutéale et poplitée]

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Background: We tested the hypothesis that using a subgluteus approach to the sciatic nerve requires a lower concentration of mepivacaine to obtain complete anesthesia as compared with the popliteal approach.

Methods: With midazolam premedication (0.05 mg·kg^{-1} *iv*), 48 patients undergoing hallux valgus repair were randomly allocated to receive a sciatic nerve block using either a posterior popliteal (group Popliteal, $n = 24$) or subgluteus (group Subgluteus, $n = 24$) approach with 30 mL of local anesthetic injected after elicitation of plantar flexion of the foot with a current ≤ 0.5 mA. A 20G catheter was inserted for 2–4 cm to supplement the block if required. The concentration of the injected solution was varied for consecutive patients using the up-and-down staircase method according to the response of the previous patient (initial concentration: 1%; up-and-down steps: 0.1%). Successful nerve block was defined as complete loss of pinprick sensation in both tibial and common peroneal nerve distributions with concomitant inability to perform plantar or dorsal flexion of the foot 30 min after injection.

Results: The minimum effective anesthetic concentration of mepivacaine resulting in complete block of the sciatic nerve in 50% of cases (ED_{50}) was 0.95% ± 0.014% (95% confidence intervals [CI_{95}]: 0.77%–1.12%) in group Subgluteus and 1.53% ± 0.453% (CI_{95}: 0.96%–2.00%) in group Popliteal ($P = 0.026$). The ED_{95} for adequate nerve block calculated with probit transformation and logistic regression analysis was 1.12% (CI_{95}: 0.71%–1.99%) in group Subgluteus and 1.98% (CI_{95}: 1.39%–2.31%) in group Popliteal.

Conclusion: A subgluteus approach to the sciatic nerve facilitates a reduction of the minimum effective concentration of local anesthetic required to produce an effective surgical block within 30 min after the injection as compared with the posterior popliteal approach.

Contexte *: Nous avons testé l'hypothèse qu'une concentration plus faible de mépivacaïne est nécessaire pour obtenir une anesthésie complète avec une approche sous-glutéale qu'avec une approche poplitée lors d'un bloc du nerf sciatique.*

Méthode *: Quarante-huit patients devant subir une réparation d'hallux valgus et ayant reçu du midazolam en prémédication (0,05 mg·kg^{-1} iv) ont été randomisés en deux groupes. Le bloc du nerf sciatique a été réalisé par une approche poplitée postérieure dans le premier groupe (groupe poplité, n = 24) et dans le second par une approche sous-glutéale (groupe sous-glutéal, n = 24) à l'aide de 30 mL d'anesthésique local injecté après élicitation de la flexion plantaire du pied avec un courant de ≤ 0,5 mA. Un cathéter de 20G a été inséré à 2-4 cm afin de compléter le bloc si nécessaire. Nous avons varié la concentration de solution injectée chez les patients consécutifs selon la méthode d'estimation par accroissement ou diminution, et ce selon la réaction du patient précédent (concentration initiale : 1 % ; accroissement ou diminution : 0,1 %). Un bloc nerveux réussi était défini comme la perte complète de sensibilité à la douleur dans les distributions des nerfs tibial et péroné commun avec une incapacité concomitante à bouger le pied (flexion plantaire ou dorsale) 30 min après l'injection.*

Résultats *: La concentration anesthésique efficace minimale de mépivacaïne ayant pour résultat un bloc complet du nerf sciatique était, dans 50 % des cas (ED_{50}), de 0,95 % ± 0,014 % (95 % intervalle de confiance [IC_{95}]: 0,77 %–1,12 %) dans le groupe sous-glutéal et de 1,53 % ± 0,453 % (IC_{95}: 0,96 %–2,00 %) dans le groupe poplité (P = 0.026). La ED_{95} pour un bloc nerveux adéquat, calculé avec la transformation de probit et une analyse de régression logistique était de 1,12 % (IC_{95}: 0,71 %–1,99 %)*

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dans le groupe sous-glutéal et de 1,98 % (IC_{95}: 1,39 %–2,31 %) dans le groupe poplité.

Conclusion *: Comparée à l'approche poplitée postérieure, l'approche sous-glutéale du nerf sciatique facilite une réduction de la concentration minimale efficace d'anesthésiques locaux nécessaire à la réalisation d'un bloc chirurgical efficace 30 min après injection.*

THE success of peripheral nerve blocks depends on the correct identification of nerve structures and injection of an adequate dose of local anesthetic around them, in order to achieve a complete impregnation of all nerves involved in surgery. Other relevant factors improving the success rate of nerve blocks include the use of a single, immobile needle injection *vs* a double injection technique,[1–4] the type of evoked motor response obtained,[5,6] the intensity of the current at which peripheral nerve stimulation is achieved,[7] and the dose of local anesthetic injected.[8]

For sciatic nerve block several approaches have been described, using different volumes and doses of local anesthetic.[8–11] Taboada *et al.*[12] recently reported that a larger volume of 1.5% mepivacaine was required to block the sciatic nerve at a more distal site as compared with a proximal injection, suggesting that the approach could represent an important factor influencing the clinical profile of nerve block. The aim of this prospective, randomized, double-blinded study was to test the hypothesis that using the subgluteus approach to the sciatic nerve reduces the minimum effective anesthetic concentration (MEAC) of mepivacaine providing adequate surgical block in 50% of patients as compared with the popliteal approach.

Methods

With Ethical Committee approval and written informed consent, 48 ASA physical status I–II patients, undergoing elective hallux valgus repair with osteotomy were enrolled. Patients with clinically significant coagulopathy, infection at the injection site, allergy to local anesthetics, severe cardiopulmonary disease, body mass index more than 35, diabetic or other neuropathies, as well as patients receiving opioids for chronic analgesic therapy were excluded.

After arrival into the operating theatre an 18G *iv* catheter was placed in the forearm contralateral to the operated limb, and standard premedication was given (midazolam 0.05 $mg \cdot kg^{-1}$ *iv*). Standard monitoring was used throughout the procedure, including non-invasive arterial blood pressure, electrocardiography (lead II), heart rate, and oxygen saturation. An experienced anesthesiologist placed all nerve blocks with the aid of a nerve stimulator (Plexygon, Vygon, France). The stimulation frequency was set at 2 Hz and pulse duration at 0.15 msec, while the stimulating intensity, initially set at 1 mA, was progressively decreased to ≤ 0.5 mA before injecting the anesthetic solution.

A femoral nerve block was first performed using a 5-cm short-bevelled, Teflon coated stimulating needle (Locoplex, Vygon, Ecouen, France) and 15 mL of 0.5% levobupivacaine (Chirocaine, Abbot, Italy) equally divided among contractions of vastus medialis, vastus intermedius and vastus lateralis muscles according to the multiple injection technique.[13] Then, using a computer-generated sequence of random numbers and a sealed envelope technique, patients were randomly allocated to receive a sciatic nerve block using either a subgluteus (group Subgluteus, $n = 24$)[9] or a posterior popliteal (group Popliteal, $n = 24$)[14] approach. For the posterior popliteal approach the needle was inserted 9 cm proximally to the popliteal crease, ideally before the bifurcation of the sciatic nerve.[14]

In both groups the sciatic nerve block was placed using a 10-cm long - 18G insulated Tuohy needle (Plexolong, Pajunk, Germany) until elicitation of a tibial nerve-mediated motor response (plantar flexion or inversion of the foot and/or flexion of the toes). If the specific tibial nerve-mediated muscular response was not observed, the insulated Tuohy needle was withdrawn at the level of the skin and reintroduced with a different angle until the proper tibial nerve-mediated response was obtained, which has been shown to be associated with improved onset time and success rate as compared with a common peroneal-mediated response.[5,6] After proper positioning of the stimulating needle, allowing the same tibial-mediated motor response to be maintained with a current intensity of 0.3–0.4 mA, and negative aspiration for blood, 30 mL of study solution was slowly injected in 5 mL increments with repeated aspirations. Afterwards, a 20G catheter was introduced through the Tuohy introducer for 2–4 cm beyond the introducer's tip. Then the Tuohy needle was removed and the catheter secured in place and covered with a transparent dressing. To keep the observer blinded to the approach used in each patient, both sites of catheter placement were then hidden with an opaque white dressing, and the pneumatic tourniquet was always placed at the calf.

The 30 mL of study solution were prepared by one of the authors not taking any part in patient management (G.A.); while both the patient and the anesthesiologist placing the block and providing clinical care of the patient during surgery were blinded to

the concentration used. The concentration of the study solution was varied for consecutive patients according to an up-and-down sequential allocation technique,[13,15] based on the response (success or failure of nerve block within 30 min after study solution injection) of the previous patient in the same group. The initial concentration used in both groups was 1% (total dose of mepivacaine: 300 mg). The outcome of each patient's response determined the concentration of local anesthetic for the following patient. When complete sensory and motor blocks of the sciatic nerve were present 30 min after the injection, the concentration used for the following patient was reduced by 0.1% (30 mg). On the other hand, when complete sensory and motor blocks of the sciatic nerve were not present 30 min after injection, the concentration used for the following patient was increased by 0.1% (30 mg).

After the sciatic catheter was adequately secured, the evolution of sensory and motor blocks on both tibial and common peroneal nerve distributions was evaluated every five minutes by an independent, blinded observer for up to 30 min after the injection. Sensory block was assessed as loss of pinprick sensation (22G hypodermic needle) in the central sensory region of the two branches of the sciatic nerve with the same stimulus delivered to the contralateral side, and scored as follows: normal sensation = no block; touch sensation but no pain = partial block; total loss of sensation = complete block. Motor block was evaluated using foot flexion and foot extension, and scored as follows: no loss of force = no block; reduced force as compared with contralateral foot = partial block; incapacity to move the ankle joint = complete motor block. Complete block of the sciatic nerve was defined as the presence of complete sensory and motor blocks in the two branches of the sciatic nerve. Patients with incomplete block of the sciatic nerve 30 min after the initial bolus received an additional 10 mL bolus of 1% lidocaine through the catheter in order to allow surgery. If this did not provide sufficient anesthesia within the following 15 min, analgesic supplementation with 0.1–0.2 mg fentanyl *iv* was given in order to complete surgery. Supplemental sedation during the procedure was also provided if requested by the patient using a target-controlled infusion of propofol (target concentrations ranging between 1.2 and 2 $\mu g \cdot mL^{-1}$). If this did not provide adequate conditions to complete surgery, the target concentration of propofol was increased to 3–4 $\mu g \cdot mL^{-1}$ and a laryngeal mask airway placed to allow completion of surgery.

Postoperative analgesia consisted of 100 mg ketoprofen *iv* every eight hours and a continuous sciatic nerve block maintained with a patient-controlled analgesia (PCA) infusion pump using 0.125% levobupivacaine (basal infusion rate: 5 $mL \cdot hr^{-1}$; incremental dose: 5 mL; lockout time: 15 min; maximum incremental doses per hour: two). Rescue opioid analgesia was also available (morphine 5 mg *sc*) if required despite the use of all PCA boluses to maintain a visual analogue scale score ≤ 4 cm.

Statistical analysis

The main outcome variable was the mean concentration of mepivacaine providing adequate block of the sciatic nerve in 50% of patients (ED_{50}). To calculate in each group the MEAC of mepivacaine providing adequate block of the sciatic nerve in 50% of patients with the sequential up-and-down allocation technique, we predetermined a minimum *a priori* number of independent negative–positive up-and-down deflections of five.[15,16] Power calculations were based on the mean and standard deviations of the ED_{50} of mepivacaine required to block the sciatic nerve previously reported with using a fixed concentration and a variable volume of local anesthetic.[12] We considered as clinically relevant a difference in the main outcome variable of 0.4%, with an effect size to standard deviation ratio of 1. A minimum of 21 patients per group were required to detect the designed difference in the MEAC of mepivacaine providing adequate sciatic nerve block in 50% of patients within 30 min after the injection, accepting a two-tailed α error of 5%, and a β error of 10%.[17]

Statistical analysis was performed using the program Systat 7.0 (SPSS, Inc., Chicago, IL, USA). The mean (95% confidence intervals) ED_{50} was calculated from the midpoints of pairs of the concentrations from consecutive patients in which a negative response (inadequate nerve block within 30 min after injection) was followed by a positive one (adequate nerve block within 30 min after injection).[15,16] The data were further analyzed with a probit transformation and a logistic regression analysis to calculate the concentration of mepivacaine required to produce sciatic nerve block within 30 min after injection in 95% of subjects (ED_{95}). Comparisons of continuous variables between the two groups were performed using the Mann-Whitney U test. Categorical variables were analyzed using a contingency table analysis with the Fisher's exact test. Continuous variables are presented as mean (± SD and/or 95% confidence intervals [CI_{95}]) or median (range). Categorical variables are presented as numbers (percentage). A value of $P \leq 0.05$ was considered significant.

TABLE I Anthropometric characteristics and duration of surgery in the two groups

	Group Subgluteus (n = 24)	*Group Popliteal (n = 24)*
Age (yr)	58 ± 8	59 ± 8
Weight (kg)	67 ± 12	67 ± 13
Height (cm)	166 ± 8	166 ± 8
Gender (male/female)	5 / 15	4 / 20
ASA physical status (I–II)	11 / 9	9 / 15
Duration of surgery (min)	62 (45–120)	69 (50–112)

Continuous variables are presented as mean (± SD) or median (range). Categorical variables are presented as numbers.

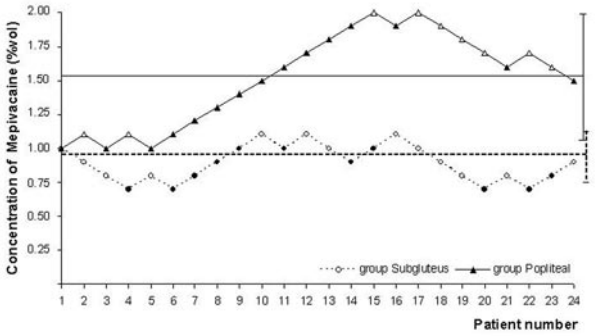

FIGURE The concentration of mepivacaine required to produce an effective block of the sciatic nerve within 30 min after injection of 30 mL of local anesthetic solution using either a subgluteus (group Subgluteus, n = 24) or popliteal (group Popliteal, n = 24) approach.
The horizontal line is the calculated mean concentration of mepivacaine providing adequate block of the sciatic nerve in 50% of patients (ED_{50}); error bars represents 95% confidence intervals; the testing interval was 0.1% (30 mg of mepivacaine); filled and empty marks represent negative and positive responses, respectively.

Results

No differences in anthropometric parameters were reported between the two groups (Table I).

The Figure shows the sequences of positive and negative responses recorded in consecutive patients in the two groups. The MEAC of mepivacaine resulting in complete block of the sciatic nerve in 50% of cases according to the up-and-down staircase method was 0.95% ± 0.014% (CI_{95}: 0.77%–1.12%) in group Subgluteus and 1.53% ± 0.453% (CI_{95}: 0.96%–2.00%) in group Popliteal (P = 0.026). The ED_{95} calculated with the probit transformation and logistic regression analysis was 1.12% (CI_{95}: 0.71%–1.99%) in group Subgluteus and 1.98% (CI_{95}: 1.39%–2.31%) in group Popliteal.

TABLE II Distribution of sensory (both tibial and common peroneal nerve distribution were considered) and motor blocks of the sciatic nerve 30 min after 30 mL of the study drug was injected using either a subgluteus (group Subgluteus, n = 24) or popliteal (group Popliteal, n = 24) approach. Data are presented as numbers.

	Group Subgluteus (n = 24)	*Group Popliteal (n = 24)*
Sensory block of the tibial nerve		
No block	0	0
Partial block	6	5
Complete block	18	19
Sensory block of the common peroneal nerve		
No block	0	0
Partial block	2	3
Complete block	22	21
Motor block		
No block	0	0
Partial block	11	15
Complete block	13	9

Eleven patients in group Subgluteus (46%) and 15 patients in group Popliteal (62%) showed a negative response 30 min after the first bolus of local anesthetic, with an incomplete block of the sciatic nerve at the end of the study. Table II shows the distribution of sensory and motor blocks recorded 30 min after the initial injection. All patients with negative response showed inadequate motor block, while a smaller proportion also showed inadequate sensory block of either the tibial or common peroneal branches. Even though the study drug was injected always at the tibial branch, the proportion of inadequate blockade of the common peroneal branch was smaller than that observed for the tibial branch. After recording the presence of a negative response according to the up-and-down sequence, these patients received a supplemental bolus of local anesthetic through the catheter and *iv* fentanyl supplementation to allow surgery. This strategy was adequate to complete surgery uneventfully in all patients but six [three (12.5%) in each group], who also required propofol sedation and laryngeal mask airway (LMA) placement to complete surgery.

No severe side effects were reported in either group, and postoperative pain control was adequate in both groups with continuous sciatic nerve block and non-steroidal anti-inflammatory drug administration at fixed intervals.

Discussion

It is well known that the success of peripheral nerve blocks is based on the accuracy with which the nerves are localized and impregnated. However, other relevant factors have been reported to affect the success rate and quality of nerve blocks, including the concentration and volume of local anesthetic injected in proximity of the nerves.[18–20] In this study we injected 30 mL of a short onset – intermediate duration local anesthetic using two different approaches to the sciatic nerve, to test the hypothesis that the approach to the nerve block can influence the MEAC required to produce adequate surgical block. Our results show that the MEAC of mepivacaine providing adequate block of the sciatic nerve is markedly affected by the approach to the block, and moving from the subgluteus to the popliteal level results in a nearly 60% increase in the MEAC of mepivacaine.

Taboada *et al.*[12] recently reported on a similar study with the same up-and-down staircase design. The up-and-down changes in the dose of mepivacaine injected in consecutive patients was the same we used in the present study (30 mg); however, in contrast with the present investigation they varied the volume and kept the concentration constant at 1.5%. The ED_{50} reported in their investigation was 12 ± 3 mL with the subgluteus approach and 20 ± 3 mL with the popliteal approach, corresponding to doses of 180 and 300 mg, respectively. These values are significantly lower than those we report in the present investigation (285 mg with the subgluteus block and 459 mg with the popliteal block). A possible explanation for this difference could be related to the different weight that volume and concentration have in driving the impregnation of nerve structures with local anesthetic molecules. In agreement with this hypothesis Vester-Andersen *et al.*[19,20] reported that increasing the concentration of local anesthetic had more influence on the quality and success rate of peripheral nerve blocks than increasing the injected volume. Another explanation for the marked difference observed in the minimum effective dose of mepivacaine reported in the present study as compared to the Taboada *et al.*'s study might be related to the fact that they injected the local anesthetic through a catheter, which was inserted 4–5 cm past the tip of the stimulating needle. In contrast, we injected the study solution directly through the stimulating needle, and then placed the catheter to supplement intraoperative analgesia in those patients with an incomplete block. It has been shown with computed tomography that at a more proximal level in the thigh, the common peroneal and tibial nerves not only are less frequently separated than at the popliteal level (27% *vs* 90% of cases), but also are much closer to each other.[21]

Apart from the difference in the absolute value of the minimum effective dose, present findings confirm Taboada *et al.*'s results.[12] This difference in the MEAC required to produce a surgical block comparing the subgluteus and popliteal approaches is reasonably related to the widening of perineural space, which is filled with adipose tissue and blood vessels.[21,22] Moreover, when evaluating the anatomy of the sciatic nerve at the subgluteal level with magnetic resonance imaging, it is clear that at this level the perineural space is much narrower, with no vessels or only a minimum vascular component.[9] This can also explain the wider confidence intervals of MEAC observed with the popliteal compared to the subgluteal approach.

The difference in the dose required to produce a successful sciatic nerve block may be clinically relevant in small patients when a combination of different blocks is required to complete surgery, because of the potential risk for drug overdosing. Such an approach-related effect might be clinically relevant also for the dose required to provide adequate postoperative analgesia; however, the present investigation was not designed to evaluate the effects of the studied approach on the minimum analgesic concentration for postoperative pain relief, and further studies are warranted to evaluate this intriguing point.

A drawback of the method used in the present investigation is that, according to the up-and-down methodology, about 50% of studied patients had an incomplete nerve block. To minimize ethical concerns of such methodology, we placed a sciatic catheter for analgesic supplementation before starting surgery. This strategy was successful, and allowed surgery to be completed uneventfully in all patients but six with a negative up-and-down response (who also required propofol sedation and LMA placement). This strategy was associated with a second limitation of the study: although the use of the double injection technique produces better results[3,4] we injected the designed volume of local anesthetic after stimulation of the tibial branch only. There were two reasons for doing this: 1) we used an 18G stimulating introducer to place the sciatic catheter; 2) we injected a large volume of local anesthetic (30 mL). Though it is not evidence based, we prefer not to move such large stimulating needles, because we do not consider it as safe as performing a multiple injection nerve block with 20-22G short bevelled, stimulating needles.[23] Moreover, double stimulation reduces the onset time and volumes required to produce a successful sciatic nerve block,[3,4] but it does not seem to produce clinically relevant dif-

ferences as compared with stimulating and injecting only at the tibial branch, when injecting ≥ 30 mL of local anesthetic.[24]

In conclusion, the present investigation demonstrated that, when using 30 mL of mepivacaine to produce a sciatic nerve block, the choice of a subgluteus rather than a popliteal approach reduces the minimum effective anesthetic concentration of local anesthetic required to produce an effective surgical block within 30 min after the injection.

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