

A Randomized, Observer-Blinded Determination of the Median Effective Volume of Local Anesthetic Required to Anesthetize the Sciatic Nerve in the Popliteal Fossa for Stimulating and Nonstimulating Perineural Catheters

Xavier Paqueron, MD, PhD,* Patrick Narchi, MD,* Jean-Xavier Mazoit, MD, PhD,†
François Singelyn, MD, PhD,* Alain Bénichou, MD,* and Philippe Macaire, MD*

Background and Objectives: Stimulating perineural catheters are developed to overcome technical problems of nonstimulating catheters, but their efficacy remains controversial. However, no volume-response study has compared success rates between stimulating and nonstimulating catheters. This study of stimulating versus nonstimulating catheters compares the minimal effective volume required to successfully block the sciatic nerve in 50% of patients scheduled for unilateral hallux valgus repair.

Methods: Patients underwent unilateral sciatic nerve block in the popliteal fossa with mepivacaine 1.5%, using either a stimulating (STIM group) or a nonstimulating (NONSTIM group) popliteal catheter. The volume of mepivacaine started at 20 mL and was increased or decreased by increments of 2 mL in subsequent patients, depending on the efficacy of the block in the previous patient, using the technique of up-down sequential allocation described by Dixon (*Neurosci Biobehav Rev*. 1991;15:47–50). Minimum effective volumes of local anesthetic were calculated using the formula of Dixon. Efficacy of block was defined by a complete sensory-motor block in the cutaneous distributions of the sciatic nerve associated with a pain-free surgery.

Results: Twenty-four patients were included in each group. Median effective volume blocking the sciatic nerve was significantly lower ($P < 0.05$) in the STIM group (2.7 mL; 95% confidence interval, 0.5–4.9 mL) compared with the NONSTIM group (16.6 mL; 95% confidence interval, 15.2–18.0 mL).

Conclusion: Stimulating popliteal catheters dramatically decrease the volume required to block the sciatic nerve in 50% of patients, compared with nonstimulating catheters.

(*Reg Anesth Pain Med* 2009;34: 290–295)

Continuous peripheral nerve blocks have become the criterion standard for analgesia after painful orthopedic surgery.¹ Stimulating perineural catheters have been developed^{2–5} to overcome the issue of postoperative analgesia failure, which has been reported in up to 40% of cases,^{6,7} although questions remain regarding their ability to reduce the failure rate of surgical anesthesia or postoperative analgesia.^{5,7–10} A recent

study showed that popliteal stimulating catheters shorten onset times of sensory and motor blocks.⁷ However, no study has ever demonstrated that such catheters permit a reduction of the volume of local anesthetics (LAs) needed to provide surgical anesthesia.

The aim of the present study was to compare the volume of LA required to provide initial surgical anesthesia during popliteal blockade with nonstimulating (NONSTIM) compared with stimulating (STIM) catheters.

Similar to studies on minimum LA concentration designed to determine the minimum effective analgesic concentrations of different LAs during epidural analgesia for labor,^{11,12} we used an up-and-down allocation method^{13,14} to compare the volumes of LA needed to provide a successful surgical sciatic nerve block in 50% of patients (ie, median effective volume, MEV50) when administered either through a STIM or a NONSTIM sciatic popliteal perineural catheter.

PATIENTS AND METHODS

After written informed consent according to the principles of the Helsinki convention and institutional review board approval were obtained, patients undergoing unilateral hallux valgus repair under continuous sciatic nerve block were enrolled in the study. All patients underwent surgery by 1 of 2 surgeons using the same surgical technique (technique of Scarf). Exclusion criteria were the existence of neurologic disease, diabetes mellitus, and cutaneous infection at the site of needle puncture. Patients were premedicated with alprazolam 0.5 mg 1 hr before surgery. No other sedation was used during block placement.

Randomization

Patients were randomly allocated to receive either a stimulating (STIM group) or a nonstimulating (NONSTIM group) popliteal catheter ($n = 24$ in each group), using a randomization table.

Popliteal Catheterization

Standard monitoring was applied to all patients. All sciatic popliteal blocks were performed by anesthesiologists experienced in the technique and by using the posterior approach described by Singelyn et al.¹⁵ After skin disinfection, an 18-gauge, 50-mm insulated needle (Stimulong 50; Pajunk, Geisingen, Germany) connected to a peripheral nerve stimulator (Multistim Sensor; Pajunk) was used to identify nerves according to their specific motor-evoked response as follows: tibial nerve—plantar flexion and/or inversion of the foot; peroneal nerve—dorsal flexion or eversion of the foot.

Motor responses were sought using the peripheral nerve stimulator set at 2-Hz frequency, 0.1-millisecond stimulating pulse duration, and an initial 1.5-mA current. In all patients, a

From the *Department of Anesthesiology and Intensive Care, Centre Clinical, Soyaux; and †University Paris-Sud, Anesthesiology Laboratory, Faculté de Médecine du Kremlin, Le Kremlin-Bicêtre, France.

Accepted for publication October 21, 2008.

Address correspondence to: Xavier Paqueron, MD, PhD, Department of Anesthesiology and Intensive Care, Centre Clinical, 2 chemin de Frégeneuil, 16800 Soyaux, France (e-mail: xavier.paqueron@orange.fr). Support was provided solely from departmental sources.

Copyright © 2009 by American Society of Regional Anesthesia and Pain Medicine

ISSN: 1098-7339

DOI: 10.1097/AAP.0b013e3181ac9be1

tibial nerve motor response (ie, plantar flexion and/or inversion of the foot) was specifically searched and considered as the needle or catheter correct end point.¹⁶ In all patients, the catheter was flushed with mepivacaine before its insertion. The initial bolus of mepivacaine was systematically injected through the catheter after it had been secured to the skin and covered with a sterile dressing.

In STIM group, after a minimal intensity of stimulation (MIS) of 0.3 to 0.5 mA had been achieved with the stimulating needle, the 20-gauge catheter with no stylet and a central opening (Stimulong 50; Pajunk) was threaded 5 cm distal to the needle tip while maintaining continuous tibial nerve stimulation with an MIS between 0.3 and 0.5 mA. In case of loss of the correct motor response (ie, plantar flexion and/or inversion of the foot), or obtaining a peroneal motor response, catheter was slightly withdrawn and reinserted until the correct end point was obtained. Time to insert the catheter (ie, from needle insertion to end of catheter insertion) and number of attempts were recorded.

In NONSTIM group, after an MIS comprised between 0.3 and 0.5 mA had been obtained, the 20-gauge catheter with no stylet and a central opening (Stimulong 50; Pajunk) was threaded 5 cm distal to the needle tip without any electrical stimulation. Time to insert the catheter (ie, from needle insertion to end of catheter insertion) was recorded.

To avoid possible overlapping of the saphenous nerve sensory area over the great toe, a saphenous nerve block was systematically performed at the inguinal level using 10 mL of 1.5% mepivacaine and systematically assessed before surgery.¹⁷ The tourniquet was placed at the distal third of the leg, just above the medial malleolus.

Up-and-Down Allocation

The initial amount of LA injected in the 2 groups was 20 mL. The volume of mepivacaine 1.5% received by a particular patient in either group was determined by the response of the previous patient (success or failure of blockade), using the Dixon up-and-down method.^{13,14} The outcome for each administration was determined by an investigator who was blinded to both the type of catheter and the volume of mepivacaine administered.

The popliteal sciatic nerve block was considered successful if we observed a complete sensory block in all cutaneous distributions of the sciatic nerve below the knee, a complete motor block by 45 mins after the initial bolus, and a total pain-free surgery. Then, the next patient of the same group had the volume of mepivacaine 1.5% decreased by 2 mL. The popliteal sciatic nerve block was considered unsuccessful if the sensory-motor block was not complete 45 mins after the administration of the initial bolus of mepivacaine 1.5% or if pain occurred during the course of surgery. Then, the next patient of the same group had the volume of mepivacaine 1.5% increased by 2 mL.

Assessment of Sensory-Motor Block

Time 0 was defined as the end of the injection of the initial bolus of mepivacaine 1.5% through the catheter. Thereafter, sensory and motor blocks were assessed 15, 30, and 45 mins by an anesthesiologist not involved in the placement of the block. Sensory block was assessed by the application of a cold pack stored in a -18°C freezer onto the skin, on a 3-point scale (2 = normal sensation, 1 = blunted sensation, and 0 = absence of sensation) in the peripheral sensory distributions of the tibial, common peroneal, deep peroneal, superficial, sural, and calcaneal nerves. A complete sensory block was defined as a score of 0 in each of the 6 areas. Otherwise, blockade was considered incomplete (score of 1 in at least 1 area).¹⁸

Motor block was assessed by asking the patient to perform successively a plantar flexion of the ankle and of the toes (tibial nerve), and dorsal flexion of the ankle and of the toes (peroneal nerve). Motor block intensity was scored using a 3-point scale (2 = normal movement, 1 = decreased movement, and 0 = no movement). Motor block was considered complete when motor response in each distribution had a score of 0; otherwise, it was considered incomplete (score of 1 for at least 1 voluntary motor response).¹⁸

To assess possible neurologic complications, the orthopedic surgeons assessed neurologic function at the time of discharge and 1 week after the procedure during the routine ambulatory visit.

Management of Block Failures

Patients who did not develop a complete sensory-motor block within 45 mins after the administration of mepivacaine 1.5% were administered a supplemental top-up with 10 mL of mepivacaine 1.5% through the catheter. Such additional bolus was not included in MEV data analysis. If a complete sensory-motor block was not achieved within 15 mins after the additional dose of mepivacaine, then either a distal block at the ankle or general anesthesia was induced at the discretion of the attending anesthesiologist.

In case of intraoperative pain or discomfort, additional small titrated intravenous doses of midazolam, sufentanil, and/or propofol were administered at the discretion of the attending anesthesiologist. In case of persistent pain, general anesthesia was induced.

Popliteal Catheter Imaging

Because the MEV50 for mepivacaine 1.5% with sciatic popliteal stimulating catheter, as determined by Taboada et al,¹⁹ was 20 mL (SD, 3 mL), we were surprised to observe such a large decrease in the volumes required to successfully block the sciatic nerve in our STIM group. This reduction of volumes raised a concern regarding the exact location of the catheter tip. Consequently, to rule out a possible intraneural insertion of the catheter, we decided to alter the study protocol to check catheter tip location, after the first success in STIM group with a volume of 10 mL. A postoperative radiologic opacification of the popliteal catheter with a nonionic radiographic contrast medium (Omnipaque 240; GE Healthcare SA, Vélizy, France) was systematically obtained in all subsequent patients of STIM group. Two consecutive radiographs of the distal tip of the catheter were obtained: the first one after administration of 1 mL and the second after injection of the same volume of dye as for the bolus of mepivacaine 1.5%. The first milliliter was injected to detect

TABLE 1. Demographic Variables

	STIM Group (n = 24)	NONSTIM Group (n = 24)
Age, mean (SD), y	58 (14)	58 (12)
Weight, mean (SD), kg	63 (7)	63 (13)
Height, mean (SD), cm	161 (7)	160 (9)
No. female/male	22/2	23/1
ASA physical status, n (%)		
I	17 (71)	16 (67)
II	7 (29)	8 (33)

ASA indicates American Society of Anesthesiologists.

TABLE 2. Characteristics of Block Placement

	STIM Group (n = 24)	NONSTIM Group (n = 24)
Duration of placement, sec	308 (211–407)	240 (180–315)
Final MIS on needle, mA		0.30 (0.28–0.38)
Final MIS on catheter	0.30 (0.26–0.34)	
Elicited motor response		
Plantar flexion	18	20
Inversion	5	4
Eversion	1	0
Catheter repositionings, n	7 (5–10)	—
Onset times, min		
Sensory block	30 (30–45)	30 (30–45)
Motor block	45 (30–45)	45 (30–45)

Values are presented as median and interquartile range, or as number.

either an intraneural catheter tip location or the intraneural diffusion of the dye. The second injection corresponding to the volume administered aimed to reproduce the spread of LA, in an attempt to understand whether the diffusion of a small volume very close to the nerve trunks over a long distance could explain the increased efficiency of the catheter.

Statistical Analysis

Statistical analysis was performed by using the Analyse-it for Microsoft Excel Software (version 2.07; Analyse-it Software, Ltd; <http://www.analyse-it.com/>; 2008). Data distribution was first evaluated using the Kolmogorov-Smirnov test. Continuous variables between groups were compared using either 2-sample Student *t* test or the Mann Whitney *U* test, according to the data distribution. Discrete variables were compared using a χ^2 test. $P < 0.05$ was considered statistically significant. Continuous variables are reported as mean (SD) or as median and interquartile range; qualitative data are presented as numbers and percentages. Twenty-four patients were enrolled in both STIM and NONSTIM groups to estimate the MEV50 providing a complete sensory-motor block of the sciatic nerve below the knee, from the up-and-down sequences by using the method of Dixon¹⁴ and Dixon and Mood.¹³ Median effective volume is reported as the mean and 95% confidence interval (CI).

RESULTS

Both groups of patients (n = 24 in each group) were comparable in terms of demographic variables (Table 1). Median duration of catheter insertion was 308 secs (interquartile range, 211–407 secs) and 240 secs (180–315 secs) in STIM and NONSTIM groups, respectively ($P = 0.13$). In STIM group, the median number of catheter repositioning during the insertion procedure was 7 (interquartile range, 5–10). Elicited motor

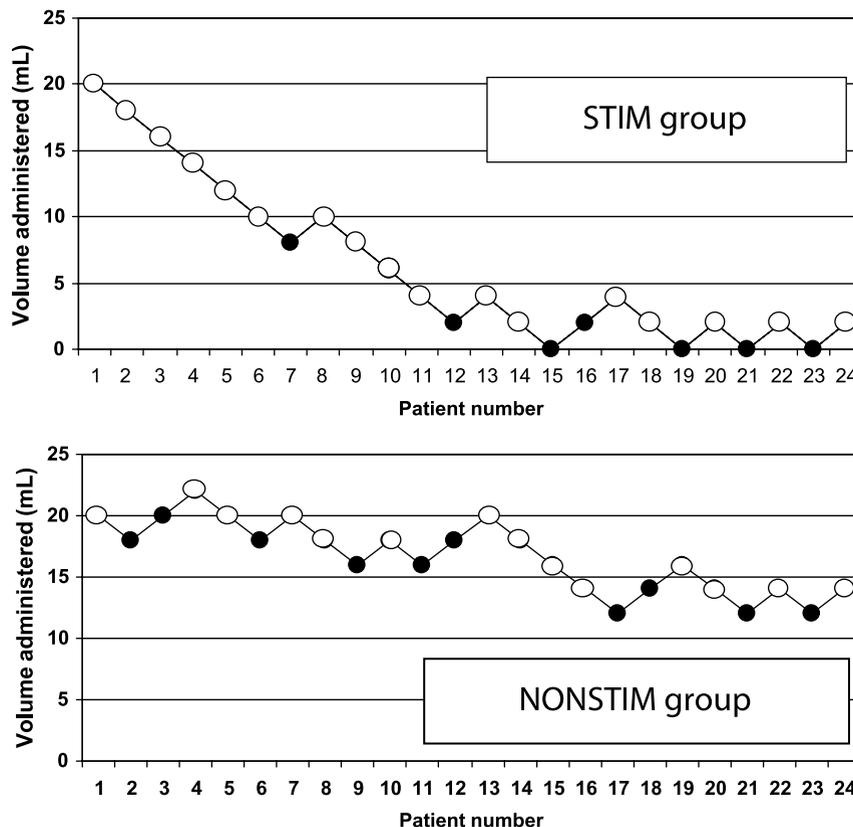


FIGURE 1. Volume of 1.5% mepivacaine administered in the 24 consecutive patients of STIM and NONSTIM groups, based on Dixon's up-and-down method. Empty and filled marks represent success and failure of blockade, respectively. The testing interval was 2 mL. The MEV50's of LA required to block the sciatic nerve were 2.7 mL (95% CI, 0.5–4.9 mL) and 16.6 mL (95% CI, 15.2–18.0 mL) in STIM and NONSTIM groups, respectively ($P < 0.05$).

responses in STIM and NONSTIM groups, respectively, were comparable (Table 2). Final MISs on the catheter and on the needle in STIM and NONSTIM groups are displayed in Table 2.

Surgical Anesthesia

Based on the up-and-down allocation method described by Dixon, the MEV50 for mepivacaine 1.5% at the popliteal level was 2.7 mL (95% CI, 0.5–4.9 mL) in the STIM group and 16.6 mL (95% CI, 15.2–18.0 mL) in the NONSTIM group ($P < 0.05$).¹⁴ The sequences of effective and ineffective popliteal nerve blocks are displayed in Fig. 1. Onset times of sensory and motor block were comparable among both groups (Table 2).

A complementary rescue bolus was administered through the catheter to make up an unsuccessful initial sensory-motor block in 5 and 8 patients of STIM and NONSTIM groups, respectively. In 2 patients of each group in whom the additional

bolus had been ineffective, general anesthesia was induced. Intraoperative sedation was administered in 1 patient of STIM group and in 2 patients of NONSTIM group.

Among patients of STIM group presenting a successful block with a volume of 4 mL or less (ie, patients 11, 13, 14, 17, 18, 20, 22, and 24 of STIM group), median duration of surgical anesthesia was 225 mins (212–246 mins).

All patients recovered uneventfully before their discharge from the institution.

Catheter Imaging

Radiographic catheter opacification was obtained in 15 patients of STIM group. In all catheters but one, diffusion of the dye into the adjacent perineural tissues occurred. Two different radiologic patterns were observed: either a spindle-shaped spread of contrast following the nerve path in a cephalic direction



FIGURE 2. Various radiographic patterns of catheter imaging. Only stimulating catheters were imaged when the random volume allocation was less than 8 mL. A first contrast bolus Omnipaque (GE Healthcare SA) of 0.5 to 1 mL was administered, followed by a contrast volume bolus similar to the initial bolus of LA administered. Among the 15 catheters that were injected with a radiographic contrast medium (Omnipaque 240; GE Healthcare SA), 2 different radiologic patterns were observed: either a spindle-shaped spread of contrast following the nerve path (injection of 1 mL [A], injection of 8 mL [B]) or a round contrast stain localized around the catheter tip (injection of 1 mL [C], injection of 8 mL [D]). In 1 patient, injection of 0.5 and 2 mL of contrast medium induced a cephalad spindle-shaped diffusion over 10 cm, without any leak, suggesting that the catheter was localized under the epineurium (injection of 0.5 mL [E], injection of 2 mL [F]).

(Figs. 2A, B), with some degree of caudal diffusion sometimes also observed, or a round contrast stain localized around the catheter tip (Figs. 2C, D). In 1 patient, injection of 0.5 and 2 mL of contrast induced a cephalad spindle-shaped diffusion over 10 cm, without any peripheral leak (Figs. 2E, F). The catheter of this patient was removed after opacification.

DISCUSSION

To the best of our knowledge, this is the first study demonstrating that compared with nonstimulating catheters, stimulating catheters reduce the volume of LA required to provide a complete sensory-motor surgical sciatic nerve block at the popliteal fossa in 50% of patients.

In a recent study on stimulating catheters, Taboada et al¹⁹ showed that the MEV50 for sciatic nerve block at the popliteal level is 20 mL (SD, 3 mL), a much greater value than that observed in our present study. No clear reason explains such a difference, except the fact that the final stimulating output current delivered via the catheter was slightly higher in the study by Taboada et al¹⁹ (0.40 mA [SD, 0.07 mA]) compared with the present one (0.30 mA [interquartile range, 0.26–0.34 mA]). All other factors such as the LA, the type of catheter, and the technique of insertion and the definition of success were similar in both studies.

The present study demonstrates that at the popliteal fossa level, stimulating catheters significantly decrease the MEV50 of LA required to block the sciatic nerve. This result could suggest, for clinical anesthesia, that the volume to be used might be lower when using stimulating compared with nonstimulating catheters. This hypothesis, if confirmed by further research, may provide at least 1 explanation to the failure of most previous studies in showing a real difference between stimulating and nonstimulating catheters, regarding initial surgical anesthesia. When considering the volume-effect relationship, the administration of 20 to 30 mL of LA, as used classically, would correspond to a point located on the right part of this curve and probably on its plateau. Then, it would be unlikely to demonstrate any difference in surgical efficacy with a particular type of catheter, because the volumes classically administered are too excessive.

Our results showing that 2.7 mL mepivacaine 1.5% is sufficient to block the sciatic nerve in 50% of patients raise the question of the exact location of the catheter tip. The present study does not provide any reasonable explanation for such a small MEV50. Our first hypothesis to try explaining this finding would be that our stimulating catheters are usually located under the epineurium of the sciatic nerve. Unfortunately, we were able to suspect this fact in 1 patient (Figs. 2E, F) only. Indeed, conventional opacification probably lacks both sensitivity and specificity to assess with accuracy catheter tip location in close vicinity of a nerve. One part of the answer has perhaps been given in a recent study on popliteal stimulating catheters by Rodriguez et al.²⁰ These authors showed very elegantly, using computed tomography, that when a low MIS is obtained during stimulating catheter insertion, the likelihood of an intraneural placement of the popliteal catheter increases.²⁰ We may then reasonably hypothesize that when using low MIS, some catheters might have been located under the epineurium.

Duration of catheter placement was comparable, although slightly shorter in the present study, to the findings of Casati et al,⁷ who found that 7 mins (SD, 2 mins) and 5 mins (SD, 2 mins) were required to place a stimulating and a nonstimulating popliteal catheter, respectively. Conversely, the number of attempts required to place the stimulating catheter with a low minimal stimulating current (approximately 0.3 mA) was higher

in the present study, when compared with other publications.^{4,21} However, end-point criteria for catheter placement were different in the present study. A minimal stimulating current of 0.30 mA (interquartile range, 0.26–0.34 mA) in the stimulating group was obtained, whereas in other studies, catheter position was considered acceptable with a final minimal stimulating current equal to or less than 0.5 mA.

In conclusion, the very low MEV50 value observed in the present study stresses the importance of taking care during catheter placement and particularly when desiring a low MIS (between 0.3 and 0.5 mA).²² It also questions the exact catheter tip location and especially the potential catheter insertion under the epineurium of the sciatic nerve. This question needs further investigation.

REFERENCES

- Klein SM. Continuous peripheral nerve blocks: fewer excuses. *Anesthesiology*. 2005;103:921–923.
- Kick O, Blanche E, Pham Dang C. A new stimulating stylet for immediate control of the catheter tip position in continuous peripheral nerve blocks. *Anesth Analg*. 1999;89:533–534.
- Boezaart AP, de Beer JF, du Toit C, van Rooyen K. A new technique of continuous interscalene nerve block. *Can J Anaesth*. 1999;46:275–281.
- Boezaart AP, De Beer JF, Nell ML. Early experience with continuous cervical paravertebral block using a stimulating catheter. *Reg Anesth Pain Med*. 2003;28:406–413.
- Pham-Dang C, Kick O, Collet T, Gouin F, Pinaud M. Continuous peripheral nerve blocks with stimulating catheters. *Reg Anesth Pain Med*. 2003;28:83–88.
- Salinas FV. Location, location, location: continuous peripheral nerve blocks and stimulating catheters. *Reg Anesth Pain Med*. 2003;28:79–82.
- Casati A, Fanelli G, Koscielniak-Nielsen Z, Cappelleri G, Aldegheri G, Danelli G, et al. Using stimulating catheters for continuous sciatic nerve block shortens onset time of surgical block and minimizes postoperative consumption of pain medication after hallux valgus repair as compared with conventional nonstimulating catheters. *Anesth Analg*. 2005;101:1192–1197.
- Morin AM, Eberhart LH, Behnke HK, Wagner S, Koch T, Wolf U, et al. Does femoral nerve catheter placement with stimulating catheters improve effective placement? A randomized, controlled, and observer-blinded trial. *Anesth Analg*. 2005;100:1503–1510.
- Chelly JE, Casati A. Are nonstimulating catheters really inappropriate for continuous nerve block techniques? *Reg Anesth Pain Med*. 2003;28:483.
- Pham Dang C, Gautheron E, Guilley J, Fernandez M, Waast D, Volteau C, et al. The value of adding sciatic block to continuous femoral block for analgesia after total knee replacement. *Reg Anesth Pain Med*. 2005;30:128–133.
- Benhamou D, Ghosh C, Mercier FJ. A randomized sequential allocation study to determine the minimum effective analgesic concentration of levobupivacaine and ropivacaine in patients receiving epidural analgesia for labor. *Anesthesiology*. 2003;99:1383–1386.
- Capogna G, Celleno D, Lyons G, Columb M, Fusco P. Minimum local analgesic concentration of extradural bupivacaine increases with progression of labour. *Br J Anaesth*. 1998;80:11–13.
- Dixon WJ, Mood AM. A method for obtaining and analysing sensitivity data. *J Am Stat Assoc*. 1948;43:109–126.
- Dixon JW. Staircase bioassay: the up-and-down method. *Neurosci Biobehav Rev*. 1991;15:47–50.
- Singelyn F, Aye F, Gouverneur JM. Continuous popliteal sciatic nerve block: an original technique to provide postoperative analgesia after foot surgery. *Anesth Analg*. 1997;84:383–386.

16. Taboada M, Atanassoff PG, Rodriguez J, Cortes J, Del Rio S, Lagunilla J, et al. Plantar flexion seems more reliable than dorsiflexion with Labat's sciatic nerve block: a prospective randomized comparison. *Anesth Analg.* 2005;100:250–254.
17. Bouaziz H, Benhamou D, Narchi P. A new approach for saphenous nerve block. *Reg Anesth.* 1996;21:490.
18. Paqueron X, Leguen M, Rosenthal D, Coriat P, Danziger N. The phenomenology of body image distortions induced by regional anaesthesia. *Brain.* 2003;126:702–712.
19. Taboada M, Rodríguez J, Valiño C, Carceller J, Bascuas B, Oliveira J, et al. What is the minimum effective volume of local anesthetic required for sciatic nerve blockade? A prospective, randomized comparison between a popliteal and a subgluteal approach. *Anesth. Analg.* 2006; 102:593–597.
20. Rodríguez J, Taboada M, Blanco M, Oliveira J, Barcena M, Alvarez J. Intraneural catheterization of the sciatic nerve in humans: a pilot study. *Reg Anesth Pain Med.* 2008;33:285–290.
21. Salinas FV, Neal JM, Sueda LA, Kopacz DJ, Liu SS. Prospective comparison of continuous femoral nerve block with nonstimulating catheter placement versus stimulating catheter-guided perineural placement in volunteers. *Reg. Anesth. Pain Med.* 2004;29:212–220.
22. Macaire P, Singelyn F, Narchi P, Paqueron X. Ultrasound or nerve stimulation guided wrist blocks for carpal tunnel release: a randomized prospective comparative study. *Reg. Anesth. Pain Med.* 2008;33:363–368.