



REVISTA BRASILEIRA DE ANESTESIOLOGIA

Official Publication of the Brazilian Society of Anesthesiology
www.sba.com.br



SCIENTIFIC ARTICLE

Determination of the minimum effective volume of 0.5% bupivacaine for ultrasound-guided axillary brachial plexus block

Leonardo Henrique Cunha Ferraro*, Alexandre Takeda,
Luiz Fernando dos Reis Falcão, André Hosoi Rezende, Eduardo Jun Sadatsune,
Maria Angela Tardelli

Disciplina de Anestesiologia, Dor e Terapia Intensiva, Escola Paulista de Medicina, Universidade Federal de São Paulo, São Paulo, SP, Brazil

Received 19 December 2012; accepted 20 March 2013

KEYWORDS

Regional anesthesia;
Brachial plexus;
Minimum volume;
Ultrasound;
Bupivacaine

Abstract

Background and objective: The use of ultrasound for needle correct placement and local anesthetic spread monitoring helped to reduce the volume of local anesthetic required for peripheral nerve blocks. There are few studies of the minimum effective volume of local anesthetic for axillary brachial plexus block. The aim of this study was to determine the minimum effective volume (VE90) of 0.5% bupivacaine with epinephrine (1:200,000) for ultrasound guided ABPB.

Method: Massey and Dixon's up-and-down method was used to calculate the minimum effective volume. The initial dose was 5 mL per nerve (radial, median, ulnar, and musculocutaneous). In case of blockade failure, the volume was increased to 0.5 mL per nerve. A successful blockade resulted in decreased volume of 0.5 mL per nerve to the next patient. Successful blockade was defined as a motor block ≤ 2 , according to the modified Bromage scale; lack of thermal sensitivity; and response to pinprick. The achievement of five cases of failure followed by success cases was defined as criterion to complete the study.

Results: 19 patients were included in the study. The minimum effective volume (VE90) of 0.5% bupivacaine with 1:200,000 epinephrine was 1.56 mL (95% CI, 0.99–3.5) per nerve.

Conclusion: This study is in agreement with some other studies, which show that it is possible to achieve surgical anesthesia with low volumes of local anesthetic for ultrasound-guided peripheral nerve blocks.

© 2013 Sociedade Brasileira de Anestesiologia. Published by Elsevier Editora Ltda. All rights reserved.

Introduction

Brachial plexus block is an anesthetic technique often used for upper limb surgical procedures. Axillary brachial plexus block (ABPB) is one of the most commonly used techniques to achieve upper limb regional anesthesia and it is performed

* Corresponding author.
E-mail: leohcferraro@yahoo.com.br (L.H.C. Ferraro).

by blocking the terminal branches of the brachial plexus, which include the musculocutaneous, ulnar, median, and radial nerves. It was believed that the failures or incomplete blockade due to this technique were the result of needle malposition or brachial plexus septa in the axillary region.¹⁻³ To increase the success rate, volume up to 80 mL have been reported.⁴ However, the use of large volumes of local anesthetic increases the likelihood of systemic toxicity.^{5,6} Thus, a possible technique to prevent this complication and increase patient safety would be to reduce the mass of the local anesthetic used during the procedure.

Currently, technologies such as peripheral nerve stimulator and ultrasound ensure the needle correct positioning in relation to the complex and reduce the need for high volumes of local anesthetic.⁷⁻¹³ Some studies have shown that the use of ultrasound reduced the volume of local anesthetic for interscalenic brachial plexus block, femoral nerve block, and ilioinguinal/iliohypogastric nerve block without compromising the quality. However, there are few studies of the minimum effective volume of local anesthetic for ABPB. Therefore, this study was performed in order to calculate the minimum effective volume of 5% bupivacaine in 90% (VE90) of cases receiving ultrasound-guided axillary brachial plexus block.

Method

Study conducted at the surgical center of the Hand and Upper Limb Unit, with the coordination of the anesthesia service for the anesthesiology, intensive care and pain discipline, Universidade Federal de São Paulo/Escola Paulista de Medicina, from December 2011 to June 2012. The study was registered at Clinicaltrials.gov under the number NCT01421914.

After approval by the Ethics Committee of the Universidade Federal de São Paulo, patients scheduled to undergo hand surgery were invited to participate in the study. Inclusion criteria were age over 18 and under 65 years, informed consent (IC) signed by the patient, indication for brachial plexus block (anesthesia and analgesia) in candidates for elective hand surgery lasting less than 2 h, ASA physical status I or II according to the American Society of Anesthesiologists, and body mass index (BMI) <35 kg/m². Exclusion criteria were cognitive impairment or active psychiatric condition, infection at the blockade puncture site, bleeding disorders, and history of allergy to bupivacaine.

Protocol design

After inclusion in the study, all patients had their demographics recorded, followed by routine surgical monitoring with ECG, noninvasive blood pressure, and pulse oximetry. Intravenous access was made in the upper limb contralateral to the procedure and maintained with crystalloid infusion.

Axillary brachial plexus block was performed using ultrasound (M-Turbo R System with HFL 38× linear transducer 6–13 MHz, SonoSite, Bothell, WA USA) and a peripheral nerve stimulator (Stimuplex R DIG RC, B. Braum, Mell-sung, Germany), with the patient in the supine position. The needle used was a 22 G × 50 mm (AEQ2250, BMD Group, Venezia, Italy). After disinfection and skin antisepsis with

chlorhexidine, the puncture site was infiltrated with 1% lidocaine. After brachial plexus nerve visualization using ultrasound, the identification of structures was confirmed with a peripheral nerve stimulator. A starting dose of 5 mL of 0.5% bupivacaine with 1:200,000 epinephrine was injected around each nerve. The needle was repositioned during local anesthetic injection, and epidural injection was ensured by ultrasound image. The patient would have been removed from the study if there were a visual change in nerve diameter or if there were a significant pain during injection. In these cases, patients were followed postoperatively for possible intraneural injection.

The end of local anesthetic injection was considered time zero to assess the blockade effectiveness. An observer who was not present during the procedure and was blinded to the volume of anesthetic used evaluated the nerve blocks studied. This assessment was done every five 5 min until surgical anesthesia was achieved or up to 30 min after local anesthetic injection.

The blockade success or failure led to the reduction or increase in the volume of local anesthetic for the next patient, respectively. When the blockade was considered effective, the subsequent patient received a reduction of 0.5 mL in the local anesthetic volume. In case of blockade failure, patients received supplemental block at the elbow level, and the local anesthetic volume for the next patient was increased by 0.5 mL. After blockade evaluation, the patients were released to the surgical procedure. During the surgical procedure, patients received propofol 15–25 mcg/kg/min for sedation. Moreover, if the patient reported pain during the procedure, the blockade was considered as a failure and general anesthesia was performed.

After surgery, the patient was admitted to the post-anesthesia care unit (PACU) and remained monitored (ECG, noninvasive blood pressure, and pulse oximetry) until meeting the required conditions for outpatient discharge. Postoperative analgesia was assessed in the PACU using a visual analog scale 3 h after the blockade.

Assessment of ABPB success

A successful blockade was considered when there were motor function ≤ 2 according to the modified Bromage scale, lack of thermal sensitivity and response to pinprick in the regions of the median, ulnar, musculocutaneous, and radial nerves. Furthermore, the procedure should be done without additional analgesia to confirm the anesthetic procedure success.

Assessment of motor function

For motor function evaluation, the modified Bromage scale was used (Table 1).

The following tests were used to assess motor function: finger flexion (median nerve), wrist extension (radial nerve), thumb adduction (ulnar nerve), and elbow flexion (musculocutaneous nerve). Values ≤ 2 according to the modified Bromage scale were considered successful blockade.

Table 1 Modified Bromage scale.

Grade	Definition
4	Full muscle strength in relevant muscle groups
3	Reduced strength, but able to move against resistance
2	Ability to move against gravity, but not against resistance
1	Discrete movements (trembling) of muscle groups
0	Lack of movement

Assessment of thermal sensitivity

The evaluation of upper limb thermal sensation was made with gauze and alcohol to test the sensitivity of the dermatomes innervated by the ulnar (hypothenar eminence), median (thenar eminence), radial (dorsum of the hand), and musculocutaneous (base of the first metacarpal) nerves. The cold sensation was regarded as 1 and lack of cold sensation as 0. A successful blockade was considered when there was no perception of cold in the dermatomes studied.

Assessment of pain sensitivity

The evaluation of upper limb pain sensation was performed with the pinprick test using a 23G needle to test sensitivity at the dermatomes areas of the ulnar, median, musculocutaneous, and radial nerves.

Positive response to pinprick was considered as 1 and lack of response to pinprick as 0. A successful blockade was regarded as the lack pinprick sensation in the dermatomes evaluated.

Criteria to complete the study

The criterion to complete the study was defined as the achievement of five cases of failure followed by success cases.

Statistical analysis

The minimum effective volume of 0.5% bupivacaine was estimated using the up-and-down sequences proposed by Dixon and Massey, focusing on analysis of the minimum effective volume with 50% probability of an effective nerve block.^{14,15} Subsequently, the sequences were also evaluated using probit regression to determine the effective volumes in 90% of cases. Nonparametric data were expressed as median and quartiles (P25–P75). Categorical data were expressed as absolute and relative frequencies. Calculations were made in Microsoft Excell spreadsheet for Windows™ (Microsoft Corp., Redmond, WA, USA) and GraphPad PRISM™ for Windows (GraphPad Software Inc, San Diego, CA, USA).

Table 2 Demographic characteristics of patients.

Age (years)	36.5 (27.5–46.5)
Gender (M:F)	14:5 (M:F)
ASA	
I	12
II	7

Table 3 Distribution of surgical procedures.

Procedures	n (%)
Metacarpal fracture	5 (26)
Synthesis material removal	1 (5)
Extensor injury	3 (16)
Scaphoid fracture repair	1 (5)
Synovectomy	3 (16)
Dupuytren	2 (11)
Flexor injury	1 (5)
Pseudoarthrosis of the phalanx	2 (11)
Excision of bone tumor	1 (5)
Duration, min (P25–75)	65 (50–77.5)

Results

The study protocol included 19 patients. In all patients it was possible to visualize the anatomical structures relevant to the blockade. The study ended when there was a sequence of five cycles of failure/success. The demographic characteristics of patients and surgical procedures performed are shown in [Tables 2 and 3](#), respectively.

The sequence of positive and negative responses to the blocks in consecutive patients is shown in [Fig. 1](#). The VE90 of 0.5% bupivacaine with 1:200,000 epinephrine for ultrasound-guided axillary brachial plexus block was 1.56 mL (95% confidence interval [CI]: 0.99–3.5).

The median latency of effective blockades was 20 min (10–30). When only the blockades with volumes of 1 mL were considered, the median latency was 25 min (20–30). For

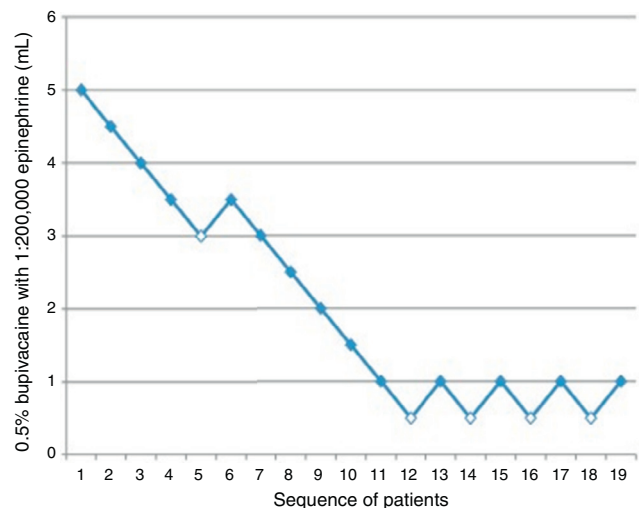


Figure 1 Graphical representation of the up-down sequence of subsequent patients. (◆), effective blockade; (◇), blockade failure.

surgical procedures in which blockades were made with 1 mL per nerve, the median duration was 60 min (35–75). Duration of sensory and motor block was not assessed in this study.

The surgical procedure was uneventful in all patients in whom the blockade was considered successful, and there was no need for additional anesthetic.

Regarding postoperative analgesia, no patient reported pain up to 3 h after the blockade. There were no complications such as vascular puncture or local anesthetic intoxication during the study. All patients were discharged on the same day of the procedure and there was no case of hospital readmission.

Discussion

In modern practice of regional anesthesia, reductions in the volume and dose of local anesthetic have become important strategies to prevent systemic toxicity by local anesthetics.

Therefore, the use of ultrasound to guide the precise location of local anesthetic injection in peripheral nerve blocks has become increasingly frequent. The advancement in ultrasound equipment and methods enabled the identification of vascular and neural structures with high accuracy, benefits compared to classical techniques, lower failure rate, and reduction of local anesthetic dosage.¹⁶

The axillary approach to brachial plexus block was chosen for this study because it is one of the most used techniques in clinical practice. Considering the territory of anesthesia provided by this blockade, only patients undergoing surgical procedures in the hands were selected.

Due to lack of knowledge about the blockade duration with low volumes of bupivacaine, it was decided to select procedures lasting less than 2 h.

This study demonstrated that with the use of ultrasound it is possible to perform the brachial plexus block achieved by axillary approach with a minimum effective volume of 0.5% bupivacaine with 1:200,000 epinephrine (1.56 mL) for each nerve in hand surgery.

O'Donnell and Iohom reported effective blockade of the brachial plexus via axillary route with 1 mL of 2% lidocaine with 1:200,000 epinephrine per nerve. However, one of the study's limitations, reported by the authors, was the choice of superficial procedures such as synovectomy or tenorrhaphies.¹⁷ Marhofer et al. described the ABPB with similar volumes of 1% mepivacaine.¹⁸ However, this was just a volunteer study in which surgical anesthesia was assessed only by pinprick test. In our study, even with low doses of local anesthetic, it was possible to perform superficial procedures, such as thumb extensor injury, and surgery with bony structures management, such as third and fourth metacarpal fractures, showing that, despite the decreased dose, it was also possible to perform procedures involving deep structures of the hand.

The choice of bupivacaine was made due to its pharmacokinetic characteristics, which provide longer lasting blockade compared to lidocaine. On the other hand, blockades with higher latency were achieved when compared with the results from the study by O'Donnell and Iohom.¹⁷

According to Hadzic, the use of low volumes of local anesthetic may result in intraneural injection because it is difficult to visualize an increase in nerve diameter in this

situation.¹⁹ In order to avoid this complication, the visualization of nerve and adjacent structures, as well as local anesthetic spread by ultrasound, is an important factor.

Our study reaffirms that the minimum effective volume for ABPB is smaller than that described previously. One possible explanation for this fact is that with the aid of ultrasound, it is possible to perform a dynamic blockade, which involves the entire nerve periphery with local anesthetic. The ultrasound allows the anesthesiologist visualization of the nerve during the blockade, which allows redirection of the needle and local anesthetic injection in the entire nerve periphery, allowing effective blockades with low volumes of local anesthetic.

Some studies have shown that low doses of local anesthetic decreased the blockade duration, defined as the time between the onset of blockade installation and the return of motor and sensory functions.²⁰ A limitation of our study was that we did not assess the blockade duration with 0.5% bupivacaine, we just found that the blockades with low doses of local anesthetic were sufficient to perform the procedures with less than 2 h duration and that all blockades had a latency less than or equal to 30 min.

The use of low doses of local anesthetic provides a safer blockade, with less risk of complications, especially related to the systemic toxicity of local anesthetics. Despite the development of effective approaches for treating these complications, such as the use of lipid emulsions,^{21,22} the use of local anesthetics at low doses promotes a blockade with an anesthetic mass with a wide range of safety for the toxic dose.

The use of low doses of local anesthetic provides a safer blockade, with less risk of complications, especially those related to the systemic toxicity of local anesthetics. Despite the development of effective approaches for treating these complications, such as the use of lipid emulsions,^{21,22} the use of local anesthetics at low doses promotes a blockade with an anesthetic mass with a wide range of safety for the toxic dose.

In summary, this study shows that the VE90 ultrasound-guided ABPB is 1.56 mL of 0.5% bupivacaine with 1:200,000 epinephrine per nerve. This corroborates some studies showing that it is possible to obtain peripheral nerve blocks with low volumes of local anesthetic. Additional studies of dose-response should be conducted to assess the influence of bupivacaine concentration for this technique.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Thompson GE, Rorie DK. Functional anatomy of the brachial plexus sheaths. *Anesthesiology*. 1983;59:117–22.
2. Klastaad O, Smedby O, Thompson GE, et al. Distribution of local anesthetic in axillary brachial plexus sheath. *Anesthesiology*. 2002;96:1315–24.
3. De Jong RH. Axillary block of the brachial plexus. *Anesthesiology*. 1961;2:215–25.
4. Vester-Andersen T, Christiansen C, Sørensen M, Kaalund-Jørgensen HO, Saugbjerg P, Schultz-Møller K. Perivascular axillary block II: influence of injected volume of local

- anaesthetic on neural blockade. *Acta Anaesthesiol Scand.* 1983;27:95–8.
5. Groban L. Central nervous system and cardiac effects from long-acting amide local anesthetic toxicity in the intact animal model. *Reg Anesth Pain Med.* 2003;28:3–11.
 6. Maher LE, Copeland SE, Ladd LA. Acute toxicity of local anesthetics: underlying pharmacokinetic and pharmacodynamic concepts. *Reg Anesth Pain Med.* 2005;30:553–66.
 7. Fredrickson MJ, Ball CM, Dalgleish AJ, et al. A prospective randomized comparison of ultrasound and neurostimulation as needle end points for interscalene catheter placement. *Anesth Analg.* 2009;108:1695–700.
 8. Gautier P, Vandepitte C, Ramquet C, DeCoopman M, Xu D, Hadzic A. The minimum effective anesthetic volume of 0,75% ropivacaine in ultrasound-guided interscalene brachial plexus block. *Anesth Analg.* 2011;113:951–5.
 9. Renes SH, Van Geffen GJ, Rettig HC, Gielen MJ, Scheffer GJ. Minimum effective volume of local anesthetic for shoulder analgesia by ultrasound-guided block at root C7 with assessment of pulmonary function. *Reg Anesth Pain Med.* 2010;35:529–34.
 10. Marhofer P, Schrogendorfer K, Wallner T, et al. Ultrasonographic guidance reduces the amount of local anesthetic for 3-in-1 blocks. *Reg Anesth Pain Med.* 1998;23:584–8.
 11. Ponrouch M, Bouic N, Bringuler S, et al. Estimation and pharmacodynamic consequences of the minimum effective anesthetic volume for median and ulnar nerve blocks: a randomized, double-blind, controlled comparison between ultrasound and nerve stimulation guidance. *Anesth Analg.* 2010;111:1059–64.
 12. Casati A, Baciarello M, Di Cianni S, et al. Effects of ultrasound guidance on the minimum effective anaesthetic volume required to block the femoral nerve. *Br J Anaesth.* 2007;98:823–7.
 13. Riazi S, Carmichael N, Awad I, et al. Effect of local anaesthetic volume (20 vs 5 mL) on the efficacy and respiratory consequences of ultrasound-guided interscalene brachial plexus block. *Br J Anaesth.* 2008;101:549–56.
 14. Dixon JW. Staircase bioassay – the up-and-down method. *Neurosci Biobehav Rev.* 1991;15:47–50.
 15. Pace NL, Stylianou MP. Advances in and limitations of up-and-down methodology: a précis of clinical use, study design and dose estimation in anesthesia research. *Anesthesiology.* 2007;107:144–52.
 16. Neal JM, Chan VW, Grant SA, et al. The ASRA evidence-based medicine assessment of ultrasound-guided regional anesthesia and pain medicine: executive summary. *Reg Anesth Pain Med.* 2010;35:S1–9.
 17. O'Donnell BD, Iohom G. An estimation of the minimum effective anesthetic volume of 2% lidocaine in ultrasound-guided axillary brachial plexus block. *Anesthesiology.* 2009;111:25–9.
 18. Marhofer P, Eichenberger U, Stockli S, Huber G, Kapral S, Curatolo M, Kettner S. Ultrasonographic guided axillary plexus blocks with low volumes of local anaesthetics: a crossover volunteer study. *Anaesthesia.* 2010;266–71.
 19. Hadzic A. Volume and dose of local anesthetic necessary to block the axillary brachial plexus using ultrasound guidance. *Anesthesiology.* 2009;111:8–9.
 20. Fredrickson MJ, White R, Danesh-Clough TK. Low-volume ultrasound-guided nerve block provides inferior postoperative analgesia compared to a higher-volume landmark technique. *Reg Anesth Pain Med.* 2011;36:393–8.
 21. Lesklw U, Weinberg GL. Lipid resuscitation for local anesthetic toxicity: is it really lifesaving? *Curr Opin Anaesthesiol.* 2009;22:667–71.
 22. Bem S, Akpa BS, Kuo I, Weinberg G. Lipid resuscitation: a life-saving antidote for local anesthetic toxicity. *Curr Pharm Biotechnol.* 2011;12:313–9.