

A Prospective, Randomized Comparison between Ultrasound and Nerve Stimulation Guidance for Multiple Injection Axillary Brachial Plexus Block

Andrea Casati, M.D.,* Giorgio Danelli, M.D.,† Marco Baciarello, M.D.,‡ Maurizio Corradi, M.D.,§ Stefania Leone, M.D.,|| Simone Di Cianni, M.D.,# Guido Fanelli, M.D.**

Background: This prospective, randomized, blinded study tested the hypothesis that ultrasound guidance can shorten the onset time of axillary brachial plexus block as compared with nerve stimulation guidance when using a multiple injection technique.

Methods: Sixty American Society of Anesthesiology physical status I-III patients receiving axillary brachial plexus block with 20 ml ropivacaine, 0.75%, using a multiple injection technique, were randomly allocated to receive either nerve stimulation (group NS, n = 30), or ultrasound guidance (group US, n = 30) for nerve location. A blinded observer recorded the onset of sensory and motor blocks, the need for general anesthesia (failed block) or greater than 100 µg fentanyl (insufficient block) to complete surgery, procedure-related pain, success rate, and patient satisfaction.

Results: The median (range) number of needle passes was 4 (3-8) in group US and 8 (5-13) in group NS ($P = 0.002$). The onset of sensory block was shorter in group US (14 ± 6 min) than in group NS (18 ± 6 min) ($P = 0.01$), whereas no differences were observed in onset of motor block (24 ± 8 min in group US and 25 ± 8 min in group NS; $P = 0.33$) and readiness to surgery (26 ± 8 min in group US and 28 ± 9 min in group NS; $P = 0.48$). No failed block was reported in either group. Insufficient block was observed in 1 patient (3%) of group US and 2 patients (6%) of group NS ($P = 0.61$). Procedure-related pain was reported in 6 patients (20%) of group US and 14 patients (48%) of group NS ($P = 0.028$); patient acceptance was similarly good in the two groups.

Conclusion: Multiple injection axillary block with ultrasound guidance provided similar success rates and comparable incidence of complication as compared with nerve stimulation guidance.

AXILLARY brachial plexus anesthesia is widely used for upper extremity surgery. Nerve stimulation has become the gold standard technique for nerve location, and the

multiple injection technique with nerve stimulation has been demonstrated to provide more effective anesthesia than either double or single injection for axillary brachial plexus block.¹

Ultrasound imaging techniques enable the anesthesiologist to secure an accurate needle position and monitor the distribution of the local anesthetic in real time, with the potential advantage of improving the quality of nerve block, shortening the latency of the block, and reducing the minimum volume required to obtain a successful nerve block.²⁻⁵

Evaluating ultrasound guidance for interscalene and axillary brachial plexus blocks, Soeding *et al.*⁶ reported that using ultrasonography significantly improved the onset and completeness of sensory and motor blocks as compared with an immobile needle single injection technique with nerve stimulation. Sites *et al.*⁷ reported significant improvement in the overall success rate of axillary block with ultrasound guidance as compared with a transarterial technique. However, no studies have compared nerve block performance with ultrasound guidance or nerve stimulation when the most effective technique for nerve blockade is used: the multiple injection technique.¹ Therefore, we conducted this prospective, randomized, observer-blinded study to test the hypothesis that ultrasound guidance can shorten the onset of axillary brachial plexus block as compared with nerve stimulation guidance for nerve location when using a multiple injection technique.

Materials and Methods

After obtaining ethics committee approval (University of Parma, Parma, Italy) and written informed consent, 60 American Society of Anesthesiologists physical status I-III patients undergoing elective upper limb surgery, including forearm, wrist, and hand procedures, were prospectively enrolled. Patients with clinically significant coagulopathy, infection at the injection site, allergy to local anesthetics, severe cardiopulmonary disease, body mass index greater than 35 kg/m², diabetes mellitus, or known neuropathies, as well as patients receiving major opioid for chronic analgesic therapy, were excluded.

After arrival in the operating room, an 18-gauge intravenous catheter was placed at the forearm contralateral

This article is accompanied by an Editorial View. Please see: Borgeat A, Capdevila X: Neurostimulation/ultrasonography: The Trojan War will not take place. ANESTHESIOLOGY 2007; 106:896-8.

* Associate Professor of Anesthesia, † Staff Anesthesiologist, ‡ Anesthesia Resident, || Anesthesia Fellow, # Anesthesia Fellow, ** Professor of Anesthesia, Department of Anesthesiology and Pain Therapy, University of Parma. § Hand Surgeon, Department of Hand Surgery, Ospedale Maggiore di Parma.

Received from the Department of Anesthesiology and Pain Therapy, University of Parma, and the Department of Hand Surgery, Ospedale Maggiore di Parma, Parma, Italy. Submitted for publication October 16, 2006. Accepted for publication January 2, 2007. Support was provided solely from institutional and/or departmental sources.

Address correspondence to Dr. Casati: Department of Anesthesiology, Ospedale Maggiore di Parma, Via Gramsci 14, 43100 Parma, Italy. andrea.casati@unipr.it. Individual article reprints may be purchased through the Journal Web site, www.anesthesiology.org.

to the operated arm, and standard premedication was given intravenously (0.03 mg/kg midazolam). Standard monitoring was used throughout the procedure, including noninvasive arterial blood pressure, heart rate, and pulse oximetry.

Using a computer-generated sequence of random numbers and a sealed envelop technique, patients were randomly allocated to receive axillary brachial plexus block using either nerve stimulation (group NS, $n = 30$) or ultrasound (group US, $n = 30$) guidance.

All blocks were placed by one of the same two investigators (A.C. or G.D.), who had substantial expertise in regional anesthesia techniques. The patients were placed in the supine position with the arm abducted to approximately 90° with the hand resting on a pillow next to the head; all blocks were performed with 20 ml ropivacaine, 0.75%.

In group NS, the nerve location was performed with the aid of a nerve stimulator (Plexygon; Vygon, Ecoen, France) using a 22-gauge, 5-cm-long, short-beveled, Teflon-coated needle (Locoplex; Vygon). The nerve stimulator was set with a pulse duration of 0.15 ms, a current intensity of 1 mA, and a frequency of 2 Hz. All four main branches were located and blocked separately with 5 ml ropivacaine, 0.75%. Nerves were located according to the specific twitches elicited by their stimulation: musculocutaneous nerve: arm flexion; radial nerve: arm and finger extension, supination; median nerve: wrist, second and third finger flexion, pronation; ulnar nerve: fourth and fifth finger flexion, thumb adduction. After the proper twitch was elicited, the stimulating intensity was progressively reduced to less than 0.5 mA maintaining the proper twitch; then, 1 ml local anesthetic was injected (Raj test⁸). After this injection stopped the twitch, the location was considered adequate, and the remaining 4 ml was injected. Then, the needle was withdrawn to the skin and redirected, looking for the following twitch.

In group US, nerve location was performed using a 5-cm, 10-MHz linear probe (LOGIQ Book XP; GE Healthcare, Milan, Italy). After examination of the anatomy of the neurovascular bundle, a 21-gauge, 10-cm-long, short-beveled, Teflon-coated needle (Locoplex) was inserted and advanced along the longitudinal axis of the ultrasound transducer so that the entire shaft of the needle would lie in the path of the ultrasound beam, and both needle shaft and tip could be visualized.⁹ Nerve stimulation was not used. Based on the anatomy, the needle insertion was performed from the lateral or medial aspects of the arm to make the access to the target nerves easier in each individual case. Then, the ulnar, radial, median, and musculocutaneous nerves were blocked separately with 5 ml local anesthetic for each nerve.³ The proper spread of the local anesthetic around the considered nerves was continuously evaluated under sonographic vision, and needle tip position was contin-

uously adjusted with minimum movements during injection under sonographic vision to optimize the impregnation of nerve structures.

The number of skin punctures and needle redirections and the occurrence of intravascular needle placement were recorded. The initial needle insertion counted as one "needle pass." Any subsequent forward movements of the needle that were preceded by retractions of the needle of at least 10 mm were counted as additional needle passes. The adjustments of the needle tip position during the injection in group US were counted as additional passes only if they required retraction and reinsertion of the needle of at least 10 mm.

Then, a blinded observer, who was not present during block placement, recorded the onset of sensory and motor blocks in the distribution of the four considered nerves every 5 min. Sensory block was assessed as loss of pinprick sensation in the central sensory region of each 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 forearm and wrist flexion/extension, thumb and second digit pinch, and thumb and fifth digit pinch, and scored as follows: no loss of force = no block; reduced force as compared with contralateral arm = partial block; incapacity to overcome gravity = complete motor block. The zero time for onset of sensory and motor blocks was the completion of local anesthetic injection. We defined as readiness for surgery the presence of complete sensory block in the four territories and complete motor block in at least three of the four nerves, with partial motor blocks in the fourth remaining nerve. If any potentially surgical territory was not completely anesthetized before surgery, the block was supplemented at the elbow or wrist and considered as failed.

The same blinded observer also recorded the presence of procedure-related pain immediately after block placement using a 10-cm visual analog scale (0 = no pain; 10 = worst imaginable pain).

In case of pain during surgery, supplementary intravenous analgesia with 50- μ g boluses of intravenous fentanyl was given. The need for more than 100 μ g fentanyl to complete surgery was considered as an insufficient block. If fentanyl supplementation (maximum dose 200 μ g) was not sufficient to complete surgery, general anesthesia was given with placement of a laryngeal mask airway, and the block was considered as failed. After the end of surgery, patients were transferred to the recovery room, and patient satisfaction was assessed using a two-point scale: 1 = good: if ever operated on again in the future, I want the same anesthetic procedure; 2 = bad: if ever operated on again in the future, I want a different anesthetic procedure.

Postoperative analgesia consisted of 100 mg intrave-

Table 1. Patient Characteristics

	Group US (n = 30)	Group NS (n = 29)
Age, yr	55 ± 17	46 ± 19
Weight, kg	70 ± 14	67 ± 13
Height, cm	170 ± 9	166 ± 8
Sex, M/F	17/13	16/13
ASA physical status, I/II/III	14/14/2	15/11/3
Duration of surgery, min	62 (20–180)	69 (25–175)
Site of surgery		
Forearm	2	2
Wrist	9	8
Hand	19	19

Anthropometric characteristics and site and duration of surgery in the two studied groups. Continuous variables are presented as mean ± SD or median (range) according to data distribution; categorical variables are presented as count.

ASA = American Society of Anesthesiologists; NS = nerve stimulation; US = ultrasound.

nous ketoprofen every 8 h and 100 mg intravenous tramadol on request.

The day after surgery, complete recovery of neurologic function on the operated limb was checked, and the occurrence of untoward events, including paresthesia, dysesthesia or motor deficits, was recorded.

The main outcome variable was the time to achieve readiness to surgery. Power calculations were based on the SD reported in previous investigations with multiple injection technique for axillary brachial plexus with 0.75% ropivacaine.^{1,10,11} We considered as clinically relevant a 5-min difference in the main outcome variable, with an effect size to SD ratio of 1. A total of 27 patients per group were required to detect the designed difference in the onset of nerve block, accepting a two-tailed α error of 5% and a β error of 10%.¹²

Statistical analysis was performed using the Systat 7.0 statistical software package (SPSS Inc., Chicago, IL). Normal distribution of the collected data was first evaluated using the Kolmogorov-Smirnov test. Continuous variables were analyzed using the Student *t* test or the Mann-Whitney U test according to data distribution. Categorical variables were analyzed using the contingency tables analysis and the Fisher exact test. Continuous variables are presented as mean (\pm SD) or median (range) according to data distribution. Categorical data are presented as number (%). A *P* value \leq 0.05 was considered as significant.

Results

No differences in anthropometric characteristics and type of surgery were reported between the two groups (table 1). In one patient of group NS, it was not possible to locate all four nerves. In this case, we used ultrasound guidance to complete block placement, and the patient was excluded from further analysis.

The median (range) number of skin punctures was 2

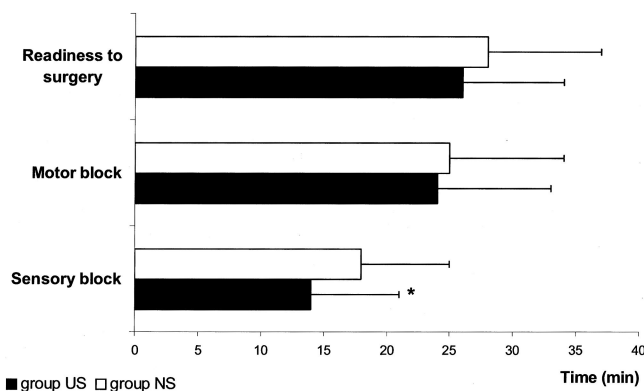


Fig. 1. Mean (\pm SD) onset times of sensory and motor blocks and readiness to surgery in patients receiving an axillary brachial plexus block with 20 ml ropivacaine, 0.75%, using either ultrasound (group US, n = 30) or nerve stimulation (group NS, n = 29) guidance for nerve location. * *P* = 0.01 as compared with group NS (Student *t* test).

(1–2) in group US and 2 (2–3) in group NS (*P* = 0.94). Group US required fewer needle passes [4 (3–8)] than group NS [8 (5–13)] (*P* = 0.002). The onset of sensory block was faster in group US than in group NS, but no differences were observed in the onset of motor block or readiness to surgery (fig. 1).

No differences in the median (range) degree of anesthesia-related pain were reported between group US [1 (0–8) cm] and group NS [3 (0–8) cm] (*P* = 0.11); however, 24 patients in group US (80%) reported no procedure-related pain as compared with only 15 patients in group NS (52%) (*P* = 0.028).

No failed block requiring rescue supplementation or general anesthesia was reported in either group. Median (range) fentanyl supplementation during surgery was similar in the two groups: 0 (0–150) μ g in group US and 0 (0–150) μ g in group NS (*P* = 0.63). Insufficient block (more than 100 μ g fentanyl required to complete surgery) was reported in one patient of group US (3%) and two patients of group NS (6%) (*P* = 0.61); these two patients of group NS (7%) also required intravenous sedation with propofol (2–3 mg \cdot kg⁻¹ \cdot h⁻¹) to alleviate anxiety (*P* = 0.25).

Patient satisfaction was similarly good in both groups: 30 patients in group US (100%) and 27 patients in group NS (93%) would accept the same anesthesia technique if needed in the future (*P* = 0.23).

No neurologic complications were reported at the 24-h follow-up, and complete recovery of sensory and motor function was observed in all studied patients.

Discussion

The success of peripheral nerve blocks is based on the ability to correctly identify nerves involved in surgery, and put an adequate dose of local anesthetic around them, to achieve a complete impregnation of all nerves

involved in surgery. The established methods of nerve location were based on either elicitation of paresthesia or identification of the proper motor response on nerve stimulation. Each of these two techniques has been reported to have a low sensitivity for detection of needle-to-nerve contact.¹³ Ultrasound guidance has been introduced into clinical practice as a possible option to identify peripheral nerves, offering the potential advantage of optimizing the spread of the local anesthetic solution around the nerves under sonographic vision.^{2-6,14-16} Nonetheless, few studies have compared ultrasound guidance with electrical nerve stimulation, and the potential advantages of sonographic guidance must be evaluated in randomized controlled trials.¹⁷

In this prospective, randomized, observer-blinded study, we compared ultrasound guidance for axillary brachial plexus block with the most effective technique of nerve stimulation, the multiple injection technique.^{1,10,11} Results showed that in experienced hands, ultrasonography and neurostimulation guidance provide similar success rates and onset times with as little as 20 ml local anesthetic solution, and a comparable incidence of complication and patient acceptance after multiple injection axillary brachial plexus block.

The onset of sensory block was 5 min faster with ultrasound guidance than with nerve stimulation. Although statistically significant, this difference is clinically questionable; moreover, no differences were reported in the onset time of motor block, readiness to surgery, and overall success rate of the block. Soeding *et al.*⁶ compared conventional "landmark-based" and ultrasound-guided brachial plexus anesthesia using both interscalene and axillary approaches, and reported that the use of ultrasonography improved the onset and completeness of sensory and motor blocks. Similar results were also reported by Williams *et al.*¹⁴ for a single injection supraclavicular block, whereas Sites *et al.*⁷ reported much better overall success rate with ultrasound guidance for axillary brachial plexus block as compared with the transarterial technique. These differences can be explained with the different technique we used as a comparator, because the multiple injection technique has been demonstrated to be the most effective nerve stimulation technique.¹ Moreover, the volume of local anesthetic we injected in our patients was 30–50% smaller than that used in these previous studies, and the onset time and success rate of axillary brachial plexus block we observed in our investigation are consistent with those previously reported in other investigations using 20 ml ropivacaine, 0.75%, and multiple injection brachial plexus block.^{18–20} It has been demonstrated that using a multiple injection technique with nerve stimulation reduces the minimum volume required to obtain a successful nerve block.^{1,21} Because the success rate of nerve block obtained with ultrasound guidance and small volumes of local anesthetic is similar to that obtained with a multiple injection technique, current results indirectly confirm conclusions of

previous investigations performed with different approaches^{2,4,5} and suggest that ultrasound guidance may allow reduction of the minimum volume of local anesthetic required to produce a successful nerve block. Properly designed trials should be advocated to evaluate this interesting potential; while considering the high success rate reported with multiple injection brachial plexus block,^{1,10} studies aimed at demonstrating a higher success rate with ultrasound guidance would require a large number of patients to be enrolled.¹⁷

With multiple injection nerve stimulation technique, all patients were expected to have a minimum of four needle passes. However, looking for all terminal nerves of axillary brachial plexus with nerve stimulation guidance usually results in even more needle passes, and the withdrawal and redirection of the stimulating needle can reduce patient acceptance, requiring implementation of sedation/analgesia to improve acceptance of the anesthesia technique.¹⁰ The current study was not powered to detect a difference in patient acceptance of the anesthesia procedure; however, it must be noticed that by reducing the number of needle passes required to complete the block, ultrasound guidance reduced the proportion of patients reporting procedure-related pain as compared with nerve stimulation.

In conclusion, in experienced hands, ultrasonography and neurostimulation have similar success rates and a comparable incidence of complication after multiple injection axillary brachial plexus block with as little as 20 ml local anesthetic solution. Patient satisfaction was similarly good with both techniques.

References

1. Handoll HH, Koscielniak-Nielsen ZJ: Single, double or multiple injection techniques for axillary brachial plexus block for hand, wrist or forearm surgery. *Cochrane Database Syst Rev* 2006; 25:CD003842
2. Marhofer P, Greher M, Kapral S: Ultrasound guidance in regional anaesthesia. *Br J Anaesth* 2005; 94:7–17
3. Grau T: Ultrasonography in the current practice of regional anaesthesia. *Best Pract Res Clin Anaesthesiol* 2005; 19:175–200
4. Marhofer P, Schrogendorfer K, Koinig H, Kapral S, Weinstabl C, Mayer N: Ultrasonographic guidance improves sensory block and onset time of three-in-one blocks. *Anesth Analg* 1997; 85:854–7
5. Marhofer P, Schrogendorfer K, Wallner T, Koinig H, Mayer N, Kapral S: Ultrasonographic guidance reduces the amount of local anesthetic for 3-in-1 blocks. *Reg Anesth Pain Med* 1998; 23:584–8
6. Soeding PE, Sha S, Royse CE, Marks P, Hoy G, Royse AG: A randomized trial of ultrasound-guided brachial plexus anaesthesia in upper limb surgery. *Anaesth Intensive Care* 2005; 33:719–25
7. Sites BD, Beach ML, Spence BC, Wiley CW, Shiffrin J, Hartman GS, Gallagher JD: Ultrasound guidance improves the success rate of perivascular axillary plexus block. *Acta Anaesthesiol Scand* 2006; 50:678–84
8. De Andres J, Sala-Blanch X: Peripheral nerve stimulation in the practice of brachial plexus anesthesia: A review. *Reg Anesth Pain Med* 2001; 26:478–83
9. Schaffhalter-Zoppoth I, McCulloch CE, Gray AT: Ultrasound visibility of needles used for regional nerve block: An *in vitro* study. *Reg Anesth Pain Med* 2004; 29:480–8
10. Fanelli G, Casati A, Garancini P, Torri G: Nerve stimulator and multiple injection technique for upper and lower limb blockade: Failure rate, patient acceptance, and neurologic complications. *Anesth Analg* 1999; 88:847–52
11. Bertini L, Tagariello V, Mancini S, Ciaschi A, Posteraro CM, Di Benedetto P, Martini O: 0.75% and 0.5% ropivacaine for axillary brachial plexus block: A clinical comparison with 0.5% bupivacaine. *Reg Anesth Pain Med* 1999; 24:514–8
12. Browner WS, Black D, Newman B, Hulley SB: Estimating sample size and

power, *Designing Clinical Research: An Epidemiologic Approach*. Edited by Hulley SB, Cummings SR. Baltimore, Williams & Wilkins, 1988, pp 139-50

13. Perlas A, Niazi A, McCartney C, Chan V, Xu D, Abbas S: The sensitivity of motor response to nerve stimulation and paresthesia for nerve localization as evaluated by ultrasound. *Reg Anesth Pain Med* 2006; 31:445-50

14. Williams SR, Chouinard P, Arcand G, Harris P, Ruel M, Boudreault D, Girard F: Ultrasound guidance speeds execution and improves the quality of supraclavicular block. *Anesth Analg* 2003; 97:1518-23

15. Chan VW, Perlas A, Rawson R, Odukoya O: Ultrasound-guided supraclavicular brachial plexus block. *Anesth Analg* 2003; 97:1514-7

16. Sandhu NS, Capan LM: Ultrasound-guided infraclavicular brachial plexus block. *Br J Anaesth* 2002; 89:254-9

17. Denny NM, Harrop-Griffiths W: Location, location, location! Ultrasound imaging in regional anaesthesia. *Br J Anaesth* 2005; 94:1-3

18. Casati A, Leoni A, Aldegheri G, Berti M, Torri G, Fanelli G: A double-blind study of axillary brachial plexus block by 0.75% ropivacaine or 2% mepivacaine. *Eur J Anaesthesiol* 1998; 15:549-52

19. Casati A, Magistris L, Beccaria P, Cappelleri G, Aldegheri G, Fanelli G: Improving postoperative analgesia after axillary brachial plexus anesthesia with 0.75% ropivacaine: A double-blind evaluation of adding clonidine. *Minerva Anesthesiol* 2001; 67:407-12

20. Fanelli G, Casati A, Beccaria P, Cappelleri G, Albertin A, Torri G: Interscalene brachial plexus anaesthesia with small volumes of ropivacaine 0.75%: Effects of the injection technique on the onset time of nerve blockade. *Eur J Anaesthesiol* 2001; 18:54-8

21. Casati A, Fanelli G, Beccaria P, Magistris L, Albertin A, Torri G: The effects of single or multiple injections on the volume of 0.5% ropivacaine required for femoral nerve blockade. *Anesth Analg* 2001; 93:183-6