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Comparison of three different volumes of mepivacaine in axillary plexus block using multiple nerve stimulation†

A. Serradell*, R. Herrero, J. A. Villanueva, J. A. Santos, J. M. Moncho and J. Masdeu

Service of Anaesthesiology and Resuscitation, Hospital de la Creu Roja, Dos de Maig 301, E-08025 Barcelona, Spain

**Corresponding author. E-mail: alecatser@telefonica.net*

Background. The multiple injection technique for axillary block, in which the four distal nerves of the plexus are located by a nerve stimulator and separately injected, has been shown to provide a high success rate and a short onset time. This randomized double-blind study was conducted to compare the effectiveness of three different volumes of mepivacaine 10 mg ml^{-1} in patients undergoing elective distal upper limb surgery under axillary brachial plexus block with the four-nerve approach. The number of complete sensory blocks was the primary efficacy variable.

Methods. A total of 114 adult patients were randomly allocated to receive 36 (n=38), 28 (n=38), and 20 ml (n=38) of mepivacaine 10 mg ml^{-1}. In each group, volumes were equally distributed in the four nerve territories. In all patients, performance time, latency time, block characteristics, need of supplementary blocks, tourniquet tolerance, duration of analgesia, and complications were recorded.

Results. Complete sensory block was obtained in 97% of patients receiving a volume of 36 ml, 97% of those receiving 28 ml, and 94% of those receiving 20 ml. One patient in the group of 28 ml and five patients in the group of 20 ml experienced pain on inflation of the tourniquet. Two months after surgery, no case of postoperative neurological dysfunction was observed.

Conclusions. The three volumes (38, 28, and 20 ml) of mepivacaine 10 mg ml^{-1} ensured a similar and high percentage of complete sensory blocks in axillary brachial plexus anaesthesia with nerve stimulation involving the location of four motor responses.

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Peripheral nerve blocks are widely used to provide anaesthesia for both upper and lower limb surgery. Success of plexus nerve block is dependent on the correct positioning of the local anaesthetic solution near the desired nerves. Demonstration of septa dividing incompletely the axillary sheath[1 2] refuted the concept of unicompartment structure[3] according to which the injected local anaesthetic solution spread easily by simple diffusion to all nerve components of the brachial plexus and constituted the anatomical basis for the single injection technique. A debate was subsequently initiated between authors advocating the single injection procedure and groups that proposed block with multiple injection techniques. Different studies have compared the results obtained with different methods of nerve location (search for paresthesia, transarterial injection, catheter insertion inside the sheath, neurostimulation) and showed that, independently of the technique used, a better success rate was obtained when dose of the anaesthetic agent was divided into two or more administrations.[4 5] Since the introduction of the nerve stimulation technique, different studies have compared the efficacy of brachial plexus block after localization of one or various responses[6–9] and showed that multiple nerve stimulation had a higher success rate than single nerve stimulation procedures. Moreover, three or four nerve response techniques were those with the highest rate of complete sensory block.[10–12]

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Multiple nerve response techniques allow the volume of anaesthetic solution to be administered to be reduced[13] as a diffusion effect through the aponeurotic sheath to reach nerves located more distally from the injection point in axillary plexus block was not necessary.

The use of the nerve stimulator and multiple injection technique allows smaller volumes of drugs to be placed closer to the nerves. We are not aware of previously published studies comparing the effectiveness of three different volumes of mepivacaine 10 mg ml^{-1} for axillary block with nerve stimulation involving the location of four motor responses.

Methods

A double-blind, randomized, three-arm parallel study was designed. The study was approved by our hospital ethical committee and all patients gave written informed consent. We studied patients of both sexes (ASA I–III) who were aged 18–80 yr and undergoing elective or acute surgery of the hand, wrist, or forearm under brachial plexus block using the four-nerve stimulation technique.

Exclusion criteria consisted of local or systemic disease that contraindicated regional anaesthesia and diseases affecting sensory or motor function of the upper extremity unrelated to the orthopaedic disorder. Patients in whom the arterial pulse was not palpated were excluded. Patients were allocated to one of three anaesthetic groups according to a table of random numbers. Patients in Group A received 36 ml of a plain solution of mepivacaine 10 mg ml^{-1}, patients in Group B received 28 ml of mepivacaine 10 mg ml^{-1}, and patients in Group C received 20 ml of mepivacaine 10 mg ml^{-1}. Patients were pre-medicated with oral lorazepam 1 mg the night before surgery and lorazepam 1 mg sublingually 1 h before operation. Before starting axillary brachial plexus block, midazolam, 1 or 2 mg according to the level of anxiety of the patient, was intravenously administered.

The technique of axillary block was the same in all patients. The arm to be operated on was abducted to at least 90° and the forearm was in flexion of 90°. The arterial pulse was palpated at the level of the major pectoral muscle crossing the axilla and the s.c. tissue overlying the artery was infiltrated with lidocaine 10 mg ml^{-1}. A 21-gauge 50-mm Teflon-coated needle (Locoplex®, Vygon, S.A., Barcelona, Spain) connected to the negative lead of the nerve stimulator (Plexival®, Medival, Italy), which was set to deliver 1 mA pulses at 2 Hz, was used. In all patients, a single puncture was performed. Nerves were located according to specific twitches elicited by their stimulation (musculocutaneous nerve: forearm flexion; median: radial flexion of the wrist, 2nd and 3rd finger flexion, pronation; ulnar: ulnar flexion of the wrist, 4th and 5th finger flexion, thumb adduction; radial: wrist and/or finger extension with or without forearm extension). Musculocutaneous and median nerves were located on the external aspect of the axillary artery, whereas ulnar and radial nerves were located on the internal aspect of the artery. This external-to-internal sequence of nerve location was consistently used in all patients. In each manoeuvre, needle position was optimized at the point of motor response when the current was decreased to equal to/less than 0.4 mA. When the location was considered adequate, predetermined volumes of mepivacaine 10 mg ml^{-1} were then injected, that is, 36 ml divided into 9 ml for each nerve in patients assigned to Group A, 28 ml divided into 7 ml for each nerve in Group B, and 20 ml divided into 5 ml for each nerve in Group C. At the end of the procedure and in order to improve tourniquet tolerance, block of the intercostobrachial and accessory of the cutaneous brachii medialis nerves was performed by administering 4 ml of the local anaesthetic subcutaneously.

The anaesthetist performing the block was aware of the site of surgery, but other staff members unaware of the patient's group evaluated the sensory and motor block. In all axillary plexus blocks performed, difficulties in location of each nerve were assessed by the anaesthetist and defined as 'easy' (one or two attempts), 'difficult' (more than two attempts), and 'not localized'.

The sensory block was assessed at 10-min intervals with a pinwheel in the skin areas supplied by the five terminal nerves: musculocutaneous (lateral side of forearm), cutaneous brachii medialis (internal forearm), median (thenar eminence), ulnar (hypothenar eminence), and radial (radial dorsum of the hand). Complete sensory block at 40 min was the primary efficacy variable. Sensory block was defined as complete when analgesia and anaesthesia was present in the five sensory areas 40 min after the end of the axillary block. The block was evaluated as incomplete when only analgesia or neither analgesia nor anaesthesia was present in any of the five sensory areas evaluated. If pain and touch sensation were felt, patients received supplementary blocks by electrolocating the nerves at the elbow (median, radial) or mid-humerus (ulnar, musculocutaneous) and the sensory assessments continued 50 and 60 min after ending of the primary block. Degree of motor block was evaluated at the same time as sensory block and defined as complete (absence of mobility) or incomplete (minor movements possible, but not against resistance, or no obvious relaxation) in relation to forearm flexion (musculocutaneous), flexion of the hand (median), abduction and adduction of the fingers (ulnar), and wrist extension (radial).

The following parameters were recorded: block performance time (from insertion to removal of the neurostimulation needle); latency time (from end of axillary block to the time the patient was declared ready for surgery, that is, analgesia and/or anaesthesia in the five sensory areas evaluated); initial tourniquet tolerance (in all cases, cuff of the tourniquet was inflated to 250 mm Hg); duration of analgesia (from end of axillary block to the start of pain sensation); and local adverse effects during block performance. Neurological sequelae (dysesthesia not related to surgery) were recorded 24 h after the operation and again 2 months later. Patient comfort during the anaesthetic

Table 1 Patient characteristics and surgical data

Variable	Mepivacaine 10 mg ml^{-1}			*P* value
	36 ml	28 ml	20 ml	
Total patients	38	38	38	
Age, yr, mean (range)	49.7 (20–78)	55.7 (18–80)	57.2 (20–77)	NS
Sex % women	63.2	52.6	65.8	NS
Weight, kg, mean (SD)	71.2 (12.7)	73.8 (16.0)	74.8 (15.6)	NS
ASA status, number (%)				NS
I	17 (44.7)	12 (31.6)	12 (31.6)	
II	16 (42.1)	18 (47.4)	18 (47.4)	
III	5 (13.2)	8 (21.1)	8 (21.1)	
Localization of surgery, number (%)				NS
Forearm	4 (10.5)	2 (5.3)	2 (5.3)	
Wrist	15 (39.5)	16 (42.1)	21 (55.3)	
Hand	19 (50.0)	20 (52.6)	15 (39.5)	
Type of procedure				NS
Soft tissue	27 (71.1)	31 (81.6)	31 (81.6)	
Osteoarticular	11 (28.9)	7 (18.4)	7 (18.4)	

Table 2 Results of axillary plexus block with multiple nerve stimulation. *Venous puncture and accidental paresthesia in one patient

Variable	Mepivacaine 10 mg ml^{-1}			*P* value
	36 ml	28 ml	20 ml	
Block performance time, min				
Mean (SD)	7.6 (2.3)	6.6 (1.6)	6.1 (1.7)	0.015
Median (range)	7.5 (4–12)	6.0 (4–10)	6.0 (3–10)	
Local adverse effects, number (%)	9 (23.7)	8 (21.1)	10 (26.3)*	NS
Venous puncture	6	6	7	
Arterial puncture	0	1	0	
Accidental paresthesia during the block	3	1	4	
Latency time, min				
Mean (SD)	22.6 (10.9)	20.8 (9.1)	21.9 (11.6)	NS
Duration of analgesia, min				
Mean (SD)	246.2 (39.4)	244.7 (36.2)	230.9 (45.0)	NS

procedure was evaluated on a VAS 0–10 scale before discharge. The patients were also asked to make a comparison between discomfort associated with insertion of the needle and use of the nerve stimulator, as well as if they would undergo the same anaesthetic procedure in the future.

The sample size was calculated according to results of a pilot study carried out at our hospital, in which the number of patients with complete sensory block at 30 min was the primary efficacy variable. Considering an alpha error of 0.05 and a beta error of 0.20, a total of 38 patients per group would be necessary to reject the null hypothesis of non-equivalence between two groups, defined as a difference of 17.3% or higher and assuming a proportion of complete sensory blocks in one of group of 90%.

Statistical analysis of data was performed with the SPSS/PC+ (version 8.0, SPSS Inc., Chicago, IL) software program. Homogeneity of the three study groups at baseline with regard to age, sex, weight, ASA status, site of operation, and type of procedure was analysed. Quantitative variables in the three study groups were compared using one-way analysis of variance (ANOVA) with Bonferroni's correction in the post-hoc analyses. The Kruskal–Wallis test was used as a non-parametric alternative. Comparison of categorical variables was carried out with the χ^2 test or the Fisher's exact test. Data are expressed as mean (SD) unless indicated otherwise.

Results

A total of 114 patients with a mean (range) age of 54 (18–80) yr were included in the study (60.5% women). There were no differences in patient characteristics, ASA status, and surgical procedures in the three study groups (Table 1). With regard to difficulties in location of each nerve, more than two attempts were required for the radial nerve in 66% of cases, musculocutaneous nerve in 45%, ulnar nerve in 41%, and median nerve in 36%. In no case could nerves not be localized.

Results of axillary plexus block are shown in Table 2. There were no differences in relation to duration of analgesia and latency time. However, mean block performance time was significantly shorter in patients receiving 20 ml mepivacaine 10 mg ml^{-1} compared with

Table 3 Assessment of sensory and motor block. *Analgesia only. †Minor movements possible, but not against resistance. ‡Two nerve territories in one patient

Variable	Mepivacaine 10 mg ml^{-1}			*P* value
	36 ml	28 ml	20 ml	
Sensory block				
Complete, number (%)	37 (97.4)	37 (97.4)	36 (94.7)	NS
Incomplete, number (%)*	1 (2.6)	1 (2.6)	2 (5.3)	
Median nerve	0	1	0	
Ulnar nerve	1	0	1	
Radial nerve	0	0	1	
Musculocutaneous nerve	0	0	0	
Cutaneous brachii medialis	0	0	0	
Motor block				
Complete, number (%)	38 (100)	36 (94.7)	34 (89.5)	NS
Incomplete, number (%)†	0	2 (5.3)	4 (10.5)‡	
Median nerve	0	1	1	
Ulnar nerve	0	0	1	
Radial nerve	0	0	2	
Musculocutaneous nerve	0	1	1	

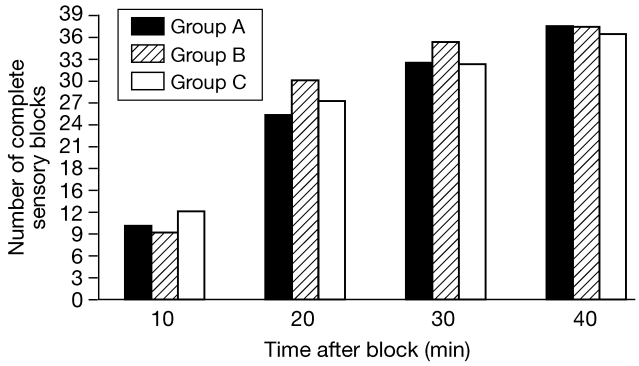

Fig 1 Number of complete sensory blocks obtained in each group at 10, 20, 30, and 40 min after the block (*P*=NS).

36 ml. Twenty episodes of vascular puncture were recorded during axillary plexus block (venous puncture in 19 cases and arterial puncture in one). The percentages of patients with complete sensory and motor blocks were similar in the three study groups (Table 3). The number of complete sensory blocks obtained in each group at 10, 20, 30, and 40 min was also similar (Fig. 1). In the four cases of incomplete sensory block (analgesia only), supplementary blocks were not performed and all patients were able to undergo surgery without the need of any additional anaesthetic technique.

In four patients with complete sensory block at 40 min (ready for surgery), surgical procedures started later than arranged for unknown reasons. These four patients (one in the group of 36 ml, one in the group of 28 ml, and two in the group of 20 ml) experienced pain in the surgical site, 170, 180, 125, and 140 min after axillary plexus block, respectively. Therefore, in order to be able to finish operation, local anaesthetic infiltration was required in two cases and a dose of fentanyl 50–75 μg was given in the remaining two. Two patients required additional sedation with midazolam due to anxiety during surgery.

Six patients had tourniquet pain. All these patients had complete sensory and motor block of the musculocutaneous nerve. As shown in Table 4, the percentage of patients experiencing tourniquet pain was higher in the 20 ml mepivacaine 10 mg ml^{-1} group, and two patients received a dose of 50 μg fentanyl for pain relief. Another patient in the 20 ml group reported tourniquet pain 70 min after the end of axillary plexus block and was treated with an additional dose of fentanyl and propofol. The level of discomfort associated with the procedure was rated similarly in the three groups; however, most patients rated nerve stimulation worse than needle insertion (Table 4).

At the 24-h postoperative assessment, five cases of dysesthesia were recorded, although none of the patients required treatment and, in all cases, dysesthesia disappeared in about 2 weeks. At the 2-month assessment, three patients reported dysesthesia that had already disappeared at the time of the visit. None of these eight patients had experienced paresthesia whilst the block was performed. A venous puncture during axillary block had occurred in one of these patients. Symptoms of anaesthetic toxicity were not reported.

Discussion

Brachial plexus block via the axillary approach is widely used in upper extremity procedures. The present results give further evidence for the high success rate obtained with peripheral nerve block performed using the multiple twitches technique with a nerve stimulator. The nerve stimulator technique allows results to be individually evaluated because the same local anaesthetic volume is used for each nerve block. In addition, the multiple injection technique offers the advantage of using smaller doses of drug, which also reduces the risk of local anaesthetic toxicity.

A consistent sequence of nerve location (from the external to the internal quadrants, i.e. musculocutaneous, median, ulnar, and radial nerves) was followed to minimize

Table 4 Assessment of tourniquet pain, comfort during the anaesthetic procedure and complications

Variable	Mepivacaine 10 mg ml^{-1}			
	36 ml	**28 ml**	**20 ml**	***P* value**
Tourniquet pain, number (%)	0	1 (2.6)	5 (13.2)	0.054
Tourniquet time, min				
Mean (SD)	34.0 (20.0)	31.6 (22.0)	30.1 (18.3)	NS
Median (range)	30 (10–100)	27.5 (10–100)	20 (15–90)	
Axillary block discomfort, VAS 0–10				
Mean (SD)	6.3 (2.5)	7.2 (1.8)	5.7 (2.4)	0.20
Needle insertion *vs* nerve stimulation, number (%)				
Equal	19 (50.0)	22 (57.9)	20 (52.6)	NS
Needle insertion worse	2 (5.3)	4 (10.5)	3 (7.9)	
Nerve stimulation worse	17 (44.7)	12 (31.6)	15 (39.5)	
Do you would undergo the same procedure in the future?				
Yes (%)	38 (100)	36 (94.7)	36 (94.7)	NS
Dysesthesia at 24 h, number	1	2	2	
Assessment at 2 months				
Between 24 h and 2 months	1	2	0	
At the control visit	0	0	0	

the risk of passing through the same zone and transfixing a potentially blocked nerve. Barker and Coventry[14] also considered that the order in which the nerves are blocked is very important and have recommended the sequence of musculocutaneous, median, and radial, with no specific localization for the ulnar nerve, providing that the radial is identified and blocked. However, accidental transfixion during location of another nerve is a criticized aspect of the multiple injection technique compared with the single injection technique.

With regard to the optimal stimulating current, it has been recently suggested that a stimulating current less than 0.5 mA should be used in every patient.[15 16] Indeed, the lower the current, the closer the nerve, and the success rate should also be higher. In our study, needle position was considered adequate at the point of motor response when the current was decreased to equal to/less than 0.4 mA. However, a distance from the nerve that is too small may cause paresthesia during puncture.[16] In our study, accidental paresthesia occurred in eight cases, a number similar or less than that reported by other authors using the multiple[17 18] or single[9] nerve stimulation techniques.

The fact that all axillary plexus blocks were performed with nerve stimulation involving the four motor responses using the same concentration of a single anaesthetic agent allow comparison between groups in latency time, level of sensory and motor block achieved, tourniquet tolerance and duration of analgesia, with doses of the anaesthetic agent contained in the different volumes assigned to each group. With regard to the primary efficacy variable (complete sensory block) it has generally been indicated that a better quality of sensory block is obtained with higher volumes. In the study of Vester-Andersen and colleagues,[19] perivascular axillary block was performed in 90 patients allocated to receive 40, 50, or 60 ml of mepivacaine 10 mg ml^{-1} with epinephrine. Although no differences were found in sensory or motor block between the three groups, a better quality of sensory block was found in the groups given 50 and 60 ml than in the group given 40 ml. In the study of Rucci and colleagues[20] using the 'orthogonal two-needle technique' and in which patients were randomly assigned to 20, 30, and 40 ml of bupivacaine with epinephrine, a better analgesic spread to all major branches of the plexus was obtained when increased volumes of anaesthetic solution were injected. Other studies have also shown that for the same amount of local anaesthetic, the larger volumes provided better quality sensory block than smaller ones.[21 22] In addition, it has been demonstrated that small volume (5 ml) injections of mepivacaine 10 mg ml^{-1} with epinephrine using the four terminal nerve technique reduced total anaesthetic time and provided better spread of analgesia in the hand than a single injection of 80 ml of the same anaesthetic solution into the neurovascular sheath.[13]

In the present study, a high rate of complete sensory block was obtained, with a success rate higher than 94% in the three study groups, including patients assigned to the lowest volume of anaesthetic solution. However, duration of the study (40 min) may account in part for the favourable results. As shown in Figure 1, 10% of patients that had a complete sensory block at the end of the study, showed incomplete sensory block at the 30-min assessment. With regard to other variables, such as latency time, duration of analgesia, and motor block, there were no statistically significant differences among the three study groups. Six patients had tourniquet pain but, in all of them, complete sensory and motor block of the musculocutaneous nerve was recorded. The poor results obtained with this technique with respect to block of the axillary nerve may justify tourniquet pain. On the other hand, muscle pain and ischaemia may be more important than cutaneous pain. A high tourniquet will often encroach on deltoid as well as the proximal cutaneous area and this may be more relevant in causing tourniquet discomfort when the axillary nerve is not blocked. In our study, tourniquet tolerance was poorer in

patients receiving 20 ml of mepivacaine 10 mg ml^{-1}. Koscielniak-Nielsen and colleagues[13] indicated that large dose and volume axillary injection provides better analgesia of the upper arm as a result of a higher incidence of block of the axillary nerve, which is responsible for sensory innervation of the external aspect of the arm. In our study, block of the intercostobrachial and accessory of the cutaneous brachii medialis nerves was performed at the end of the axillary brachial plexus block to improve tourniquet tolerance.

Overall, the study group in which a volume of 7 ml of mepivacaine 10 mg ml^{-1} was used to block each of the four motor responses (Group B), showed a success rate of complete sensory block, motor block, and tourniquet tolerance similar to the study group given a volume of 9 ml (Group A), with the further advantage of a lower risk of systemic toxicity associated with larger volumes of local anaesthetic agents. In the study of Bertini and colleagues[23] comparing the efficacy of ropivacaine and bupivacaine, a dose equivalent to that given to our patients in Group B provided an excellent level of sensory block and no patient needed additional block for surgical or tourniquet pain.

In summary, the three volumes (38 ml, 28 ml, 20 ml) of mepivacaine 10 mg ml^{-1} ensured a similar and high percentage of complete sensory blocks in axillary brachial plexus anaesthesia with nerve stimulation involving the location of four motor responses. Axillary block using an adequate concentration of a local anaesthetic agent, and the approach of multiple injection sites with stimulation of all four major nerves of the brachial plexus, may contribute to minimize the importance of the injected volume of anaesthetic solution.

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