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ORIGINAL RESEARCH

Comparison of perineural brachial plexus block and proximal perivascular block in ultrasound-guided axillary brachial plexus block

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Abstract

The traditional axillary perineural (PN) approach for brachial plexus block is frequently used, but separate musculocutaneous nerve (MCN) block is required and increases procedure time and patient discomfort. We hypothesized that a block using the proximal perivascular (PPV) method at the MCN branching from the lateral cord would obviate the need for an MCN block while ensuring a quality similar to that of the PN method. For the PN group (n = 25), a needle was placed on each nerve, and 8 mL local anesthetic was infiltrated around the radial, ulnar, and median nerves (total: 24 mL). We then injected 6 mL local anesthetic around the MCN. In the PPV group (n = 25), we moved the probe proximally until the branching junction of the the MCN in the lateral cord. The needle tips were placed in the 12-o'clock and 6-o'clock positions of the axillary artery, and 15 mL local anesthetic was injected (total: 30 mL). The procedure time, number of needle passes, procedure-related complications, sensory/motor block level, and onset time were recorded. The PPV group had a significantly shorter procedure time than the PN group (3.9 $\pm$ 1.0 *vs.* 7.5 $\pm$ 3.3 min, $p < 0.001$). Furthermore, the PPV group required fewer needle passes. The PN group showed a significantly faster onset time than the PPV group (6.4 $\pm$ 2.7 *vs.* 10.4 $\pm$ 2.9 min, $p < 0.001$). The induction time did not show significant intergroup difference. Sensory blockade in the PN group occurred significantly faster than that in the PPV group at 5 and 10 min. There were no significant differences in motor nerve paralysis. PPV axillary block under ultrasound guidance was as effective as the PN axillary block. Therefore, the PPV axillary block is a simple, safe and effective regional technique for upper limb surgery.

Keywords

Brachial plexus block; Mepivacaine; Musculocutaneous nerve; Ultrasonography

1. Introduction

When various surgeries and procedures are performed on the forearm, anesthesia is required to reduce the patient's pain and discomfort and to facilitate operative procedures [1]. Brachial plexus block (BPB) constitutes a good option for forearm surgery because it decreases postoperative pain and enables early recovery and discharge after surgery [1]. The introduction of ultrasound has significantly improved the success rate and reduced the complications of BPB [2, 3]. Ultrasonic guidance shows the anatomical structures in a targeted area and the route of the injection needle in real time [3, 4]. Various ultrasound injection techniques have been studied to increase the effectiveness of BPB [2, 5–8]. Ultrasound guidance not only facilitates the anesthetic procedure, but also decreases the dose of local anesthetics [9–11].

The most commonly used methods are perineural (PN) and perivascular (PV) injections. The traditional PN approach for brachial plexus block is a commonly performed and successful method for upper-extremity surgery, but requires separate nerve branch block procedures (radial, ulnar, median and musculocutaneous nerve), resulting in longer procedure time, patient discomfort, and the risk of nerve injury due to lack of experience, skill and anatomical variation.

The PV approach involves locating the axillary artery and infiltrating the local anesthetics around the axillary artery. The PV approach proved effective in several studies that showed faster onset time with shorter procedure time, fewer needle passes, and less discomfort and pain associated with the procedure [2]. Both the PN and PV methods are needed to block the musculocutaneous (MC) nerve separately because the nerve is not in the vicinity of the artery. The omission of this separated nerve block can simplify and facilitate the procedure as well as decrease patient discomfort.

The authors hypothesized that performing a perivascular block at the location of the proximal part of the brachial plexus

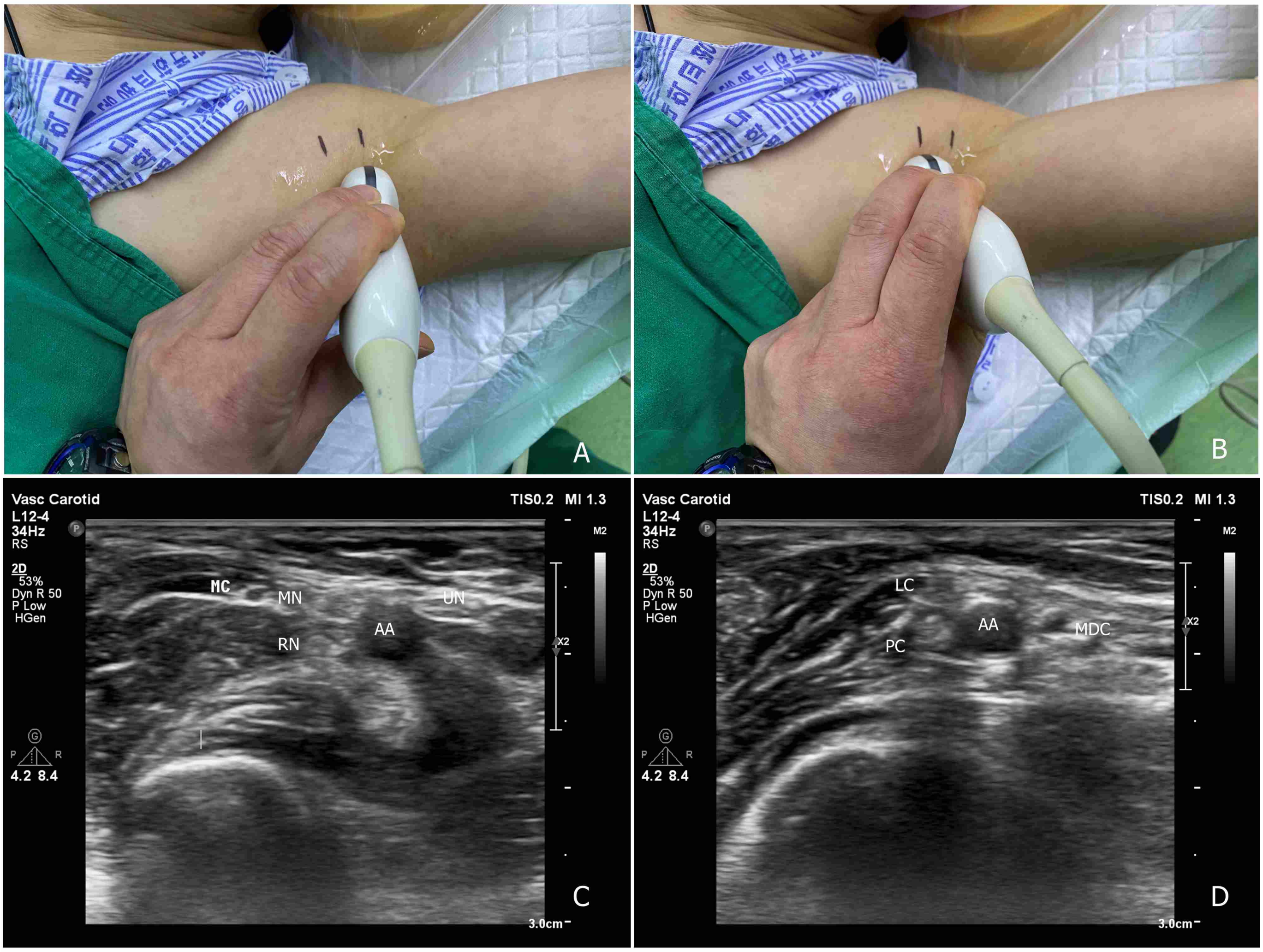

FIGURE 1. Ultrasound images of the brachial plexus and the position of the ultrasound probe. (A) brachial plexus with four nerve branches, including the median (MN), ulnar (UN), radial (RN), and musculocutaneous (MC) nerves. (B) Brachial plexus with three cords: the lateral cord (LC), medial cord (MDC) and posterior cord (PC). (C): Ultrasound image of Fig. 1A. (D) Ultrasound image of Fig. 1B.

from which the MC nerve originates (proximal perivascular block, PPV) would eliminate the need for an additional MC block, shorten the procedure time, reduce the number of needle pass, reduce discomfort, and have no difference in efficiency compared with the existing PN method (Figs. 1,2).

2. Materials and Methods

The subjects were adult patients (20–86 years old) with American Society of Anesthesiologists physical status classifications (ASA) of I, II and III. Exclusion criteria were age <18 years, anticoagulation therapy, pregnancy, infection in the injection area, allergy to local anesthetics, and any disorders that impair communication. Patients were randomly assigned to one of two groups using a computerized randomization program and sealed envelopes, with 25 patients in each group.

The patients fasted for 8 hours, and no premedication was administered. Two experienced anesthesiologists who performed more than 50 ultrasound-guided nerve blocks performed the procedures. Standard monitoring was initiated, including electrocardiography, continuous noninvasive blood pressure, and pulse oximetry. The patients were placed in a supine position, with their arms positioned at 90° shoulder abduction and 90° elbow flexion. A sterile drape was placed on the axillary area with 10% povidone-iodine solution.

We used an Affinity 70 ultrasound system (Phillips Healthcare, Bothell, WA, USA) with a 12-4 MHz linear ultrasound probe. The ultrasound probe was placed on the axillary fold, and the axillary artery, vein, and nerves were noted in the short-axis view. In this view, the 12-o'clock position faced anteriorly and closest to the skin, and the 6-o'clock position was the posterior aspect of the axillary artery. The block was performed using an in-plane approach with a 22-gauge, 80-mm needle (Stimuplex®, B. Braun, Melsungen, Germany). We administered 1.5% mepivacaine with epinephrine 5 μg/mL and 8.4% sodium bicarbonate 0.1 mEq/mL.

In the PN group, each nerve of the brachial plexus was identified using ultrasound. The needle was placed on each nerve under in-plane ultrasound guidance, and 8 mL local anesthetic was infiltrated around the nerve after careful aspiration of blood (total 24 mL). Then, the MC nerve was identified, and 6 mL local anesthetic was infiltrated around the nerve. In

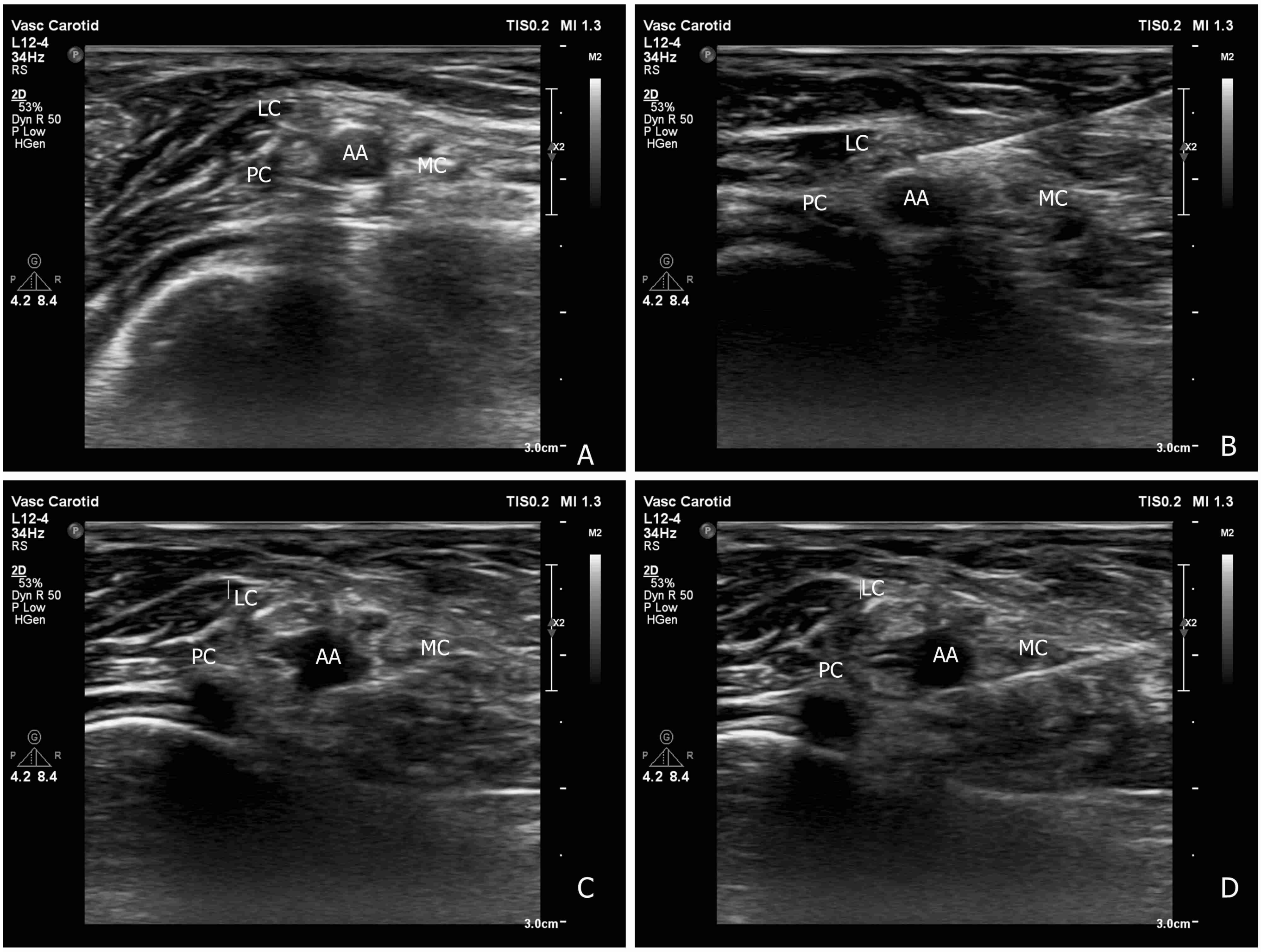

FIGURE 2. Ultrasound image of the proximal perivascular block. (A) Brachial plexus with three cords: the lateral cord (LC), medial cord (MDC), and posterior cord (PC). (B) Needle was inserted in the 12-o'clock direction of the axillary artery, and local anesthetic was injected. (C) Blurring of the axillary artery wall (Silhouette sign). (D) The needle was inserted in the 6-o'clock direction from the axillary artery.

the PPV group, we identified the axillary artery and brachial plexus. The probe was then moved proximally until it was located at the junction of the MC nerve into the lateral cord. At this position, the needle tip was placed in the 12-o'clock and 6-o'clock positions of the axillary artery, and 15 mL local anesthetic was injected into each place after careful aspiration of blood (total 30 mL). MC nerve block was not performed in this group. If the patient's body weight was <60 kg, 7 mg/kg of mepivacaine was used to perform the procedure. For example, if the body weight was 50 kg, then mepivacaine 350 mg (23.3 mL of 1.5% mepivacaine) was divided into two separate doses (11.6 mL for 12- and 6-o'clock positions) for the PPV group. The mepivacaine dose was divided into four doses (approximately 6 mL for each nerve) in the PN group.

After the nerve block, the anesthetic procedure time (the time from needle insertion to needle removal), number of needle insertions, neural irritation signs (sharp pain, tingling sensation), and vascular puncture were recorded. A blinded observer checked the degree of sensory and motor blockade, onset time (from needle removal to surgical anesthesia), and induction time (the sum of the procedure time and onset time).

Sensory and motor blockade was evaluated according to the dermatome of each nerve at every 5-minute interval (5, 10, and 15 min). Sensory blockade was evaluated using the pinprick test (grade 0, no block; grade 1, no pain sensation). The test dermatomes were as follows: radial nerve, back of the second finger; median nerve, palm side of the third finger; ulnar nerve, tip of the fifth finger; MC nerve, lateral portion of the forearm. Motor blockade was checked and graded as follows: grade 0, no weakness; grade 1, incomplete motor block; and grade 2, complete motor block. The areas where the motor nerve block was measured were as follows: radial nerve, abduction of the thumb; median nerve, flexion of the second and third fingers; ulnar nerve, flexion of the fourth and fifth fingers; and MC nerve, flexion of the elbow.

Surgical anesthesia was confirmed when the sensory blockade was grade 1 and the motor blockade was grade 1 or 2 in all four nerves. If surgical anesthesia was not ensured within 15 min, block failure was considered and general anesthesia was initiated.

After confirming surgical anesthesia, perioperative sedation was performed with dexmedetomidine infusion (loading dose

TABLE 1. Patient characteristics.

Patient characteristics	Proximal perivascular group	Perineural group	*p*-value
Age (years)	53.4 ± 18.2	56.4 ± 17.6	0.681
Body weight (kg)	65.8 ± 13.1	70.4 ± 17.3	0.427
Height (cm)	163.7 ± 8.9	162.8 ± 11.4	0.287
Sex (male/female)	11 (44%)/14 (56%)	9 (36%)/16 (64%)	0.773
ASA Classification (Class I/II/III)	8 (32%)/9 (36%)/8 (32%)	4 (16%)/7 (28%)/14 (56%)	0.200

Continuous variables are presented as mean ± standard deviation. Categorical variables are presented as counts. ASA: American Society of Anesthesiologists.

1 μg/kg for 10 min, followed by 0.5 μg/kg/h). Perioperative complications, including local anesthetic toxicity, hematoma, and nerve damage, were monitored.

The primary study outcomes were the procedure time, onset of sensory nerve block, and motor nerve paralysis. The secondary outcomes were induction time, number of needle passes, and complications related to anesthesia, including paresthesia, neural damage, vascular puncture, and hematoma.

We performed a pilot study (n = 10) with induction times of 203 ± 63 s in the PPV group and 423 ± 164 s in the PN group. The power analysis indicated that 19 patients per group would be sufficient to detect the difference in the induction time with a power of 90% at a significance level of 0.05. We included 25 patients in each group.

Data were analyzed using SPSS 18.0 for Windows (SPSS, Chicago, IL, USA). Age, body weight, and height were compared using the Mann-Whitney U test. Sex, ASA grade, sensory and motor nerve block grade, success rate, and post-procedural complications were tested using the chi-square test and Fisher's exact test. Statistical significance was set at $p < 0.05$.

3. Results

There were no statistically significant intergroup differences in age, height, body weight, sex or ASA classification (Table 1). The PPV group showed a significantly shorter procedure time than the PN group (3.9 ± 1.0 *vs.* 7.5 ± 3.3 min; $p < 0.001$). The PN group showed a significantly faster onset time than the PPV group (6.4 ± 2.7 min *vs.* 10.4 ± 2.9 min; $p < 0.001$). The induction time did not differ significantly between the groups. One case of block failure occurred in the PPV group, and general anesthesia was administered.

The sensory blockade of the PN group was significantly faster than that of the PPV group (radial and median nerves, 5 minutes; ulnar and MC nerves, 5 minutes and 10 minutes) during the early period. However, after 15 min, no significant difference was observed between the two groups (Fig. 3). There were no significant differences in motor nerve paralysis between the two groups (Fig. 4). None of the patients in either group complained of pain or discomfort during surgery. The number of needle passes in the PPV group was significantly lower than that in the PN group (2.16 ± 0.37 *vs.* 4.96 ± 1.43; $p < 0.001$). Paresthesia was noted eight times (32%) in the PN group, but not in the PPV group. Neither group had local anesthetic toxicity, neural injury, vascular puncture or hematoma.

4. Discussion

We compared the PN method and cord-level PPV method without MC nerve block in this prospective, randomized, observer-blinded trial. Our results showed that both methods effectively induced surgical anesthesia. As expected, the PPV block exhibited a significantly shorter performance time. However, the PN group showed a significantly shorter onset time and no significant difference in the induction time (Table 2). The PPV group had fewer needle passes (Table 2). One failed case was reported in the PPV group.

The procedure time of the PPV group was 3.9 ± 1.0 min and this was significantly shorter than that of the PN group (7.5 ± 3.3 min). We used PPV injections of two separate doses in the 6- and 12-o'clock areas and omitted the MC nerve block. Except for one failed case, the PPV group showed successful MC nerve block without a separate MC nerve block procedure. The procedure time was similar to that in other studies using a 6- or 12-o'clock perivascular single shot with a MC nerve block [5, 6]. Tran *et al.* [12] reported two, three, and four perivascular injection techniques, with procedure times of 574 ± 206, 603 ± 205 and 673 ± 218 s, respectively. Vastrad *et al.* [2] used two separate doses on the 6- and 12-o'clock areas of the axillary artery and separated the MC nerve block, and their procedure time was 8.647 ± 0.5486 min. The more separated nerve block procedure will result in a longer procedure time and patient discomfort. This difference depends not only on the choice of method but also on the experience of the anesthetist. Tran *et al.* [12] reported a relatively longer procedure time, and residents, fellows, and staff anesthesiologists performed the procedures. In our study, only two experienced anesthesiologists performed the procedure.

The onset time after the procedure was significantly shorter in the PN group (6.4 ± 2.7) than in the PPV group (10.4 ± 2.9). However, the induction time (procedure time + onset time) was not significantly different (PPV group *vs.* PN group: 14.3 ± 2.9 *vs.* 13.9 ± 3.4). Bernucci *et al.* [13] reported similar results (procedure time: 8.2 min *vs.* 15.7 min; onset time: 18.9 min *vs.* 13.8 min; induction time: 27.1 min *vs.* 29.0 min). Bernucci *et al.* [13] reported that selectively targeting each nerve increased the speed of the nerve block. Bupivacaine blocks showed a slower induction time than lidocaine or mepivacaine. The longer procedure time in the PN group may offset the time

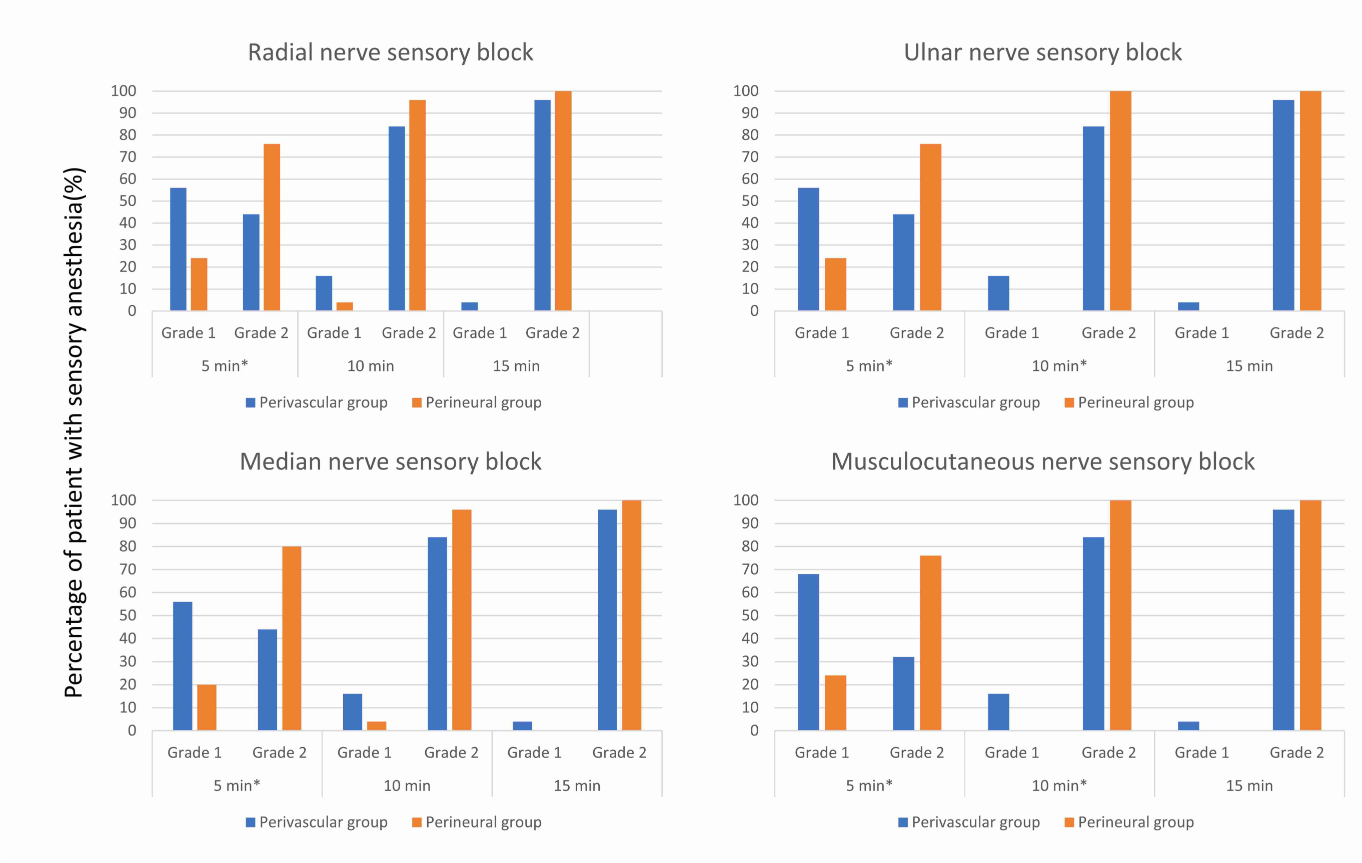

FIGURE 3. Percentage of patients with sensory anesthesia (pinprick) according to time in the cutaneous distribution of the radial, ulnar, median, and musculocutaneous nerves. The perineural group shows significantly faster blockade in all 4 nerves in 5 minutes and 2 nerves (ulnar and musculocutaneous nerves) in 10 minutes.

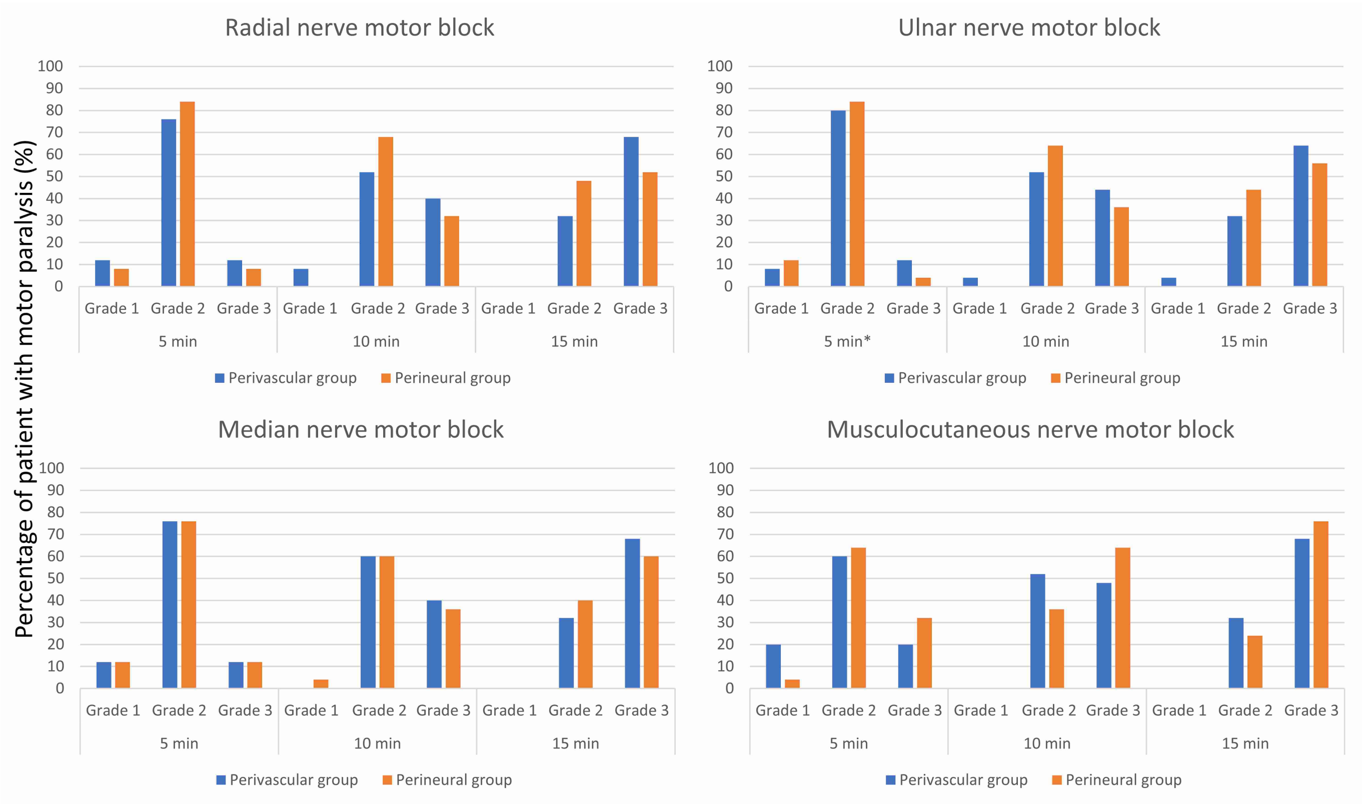

FIGURE 4. Percentage of patients with motor paralysis according to time in the distribution of the radial, ulnar, median, and musculocutaneous nerves. There was no significant difference between the two groups.

TABLE 2. Block performance data.

	Proximal perivascular group (n = 25)	Perineural group (n = 25)	p-value
Procedure time (min)	3.9 ± 1.0	7.5 ± 3.3	<0.001*
Onset time (min)	10.4 ± 2.9	6.4 ± 2.7	<0.001*
Induction time (min)	14.3 ± 2.9	13.9 ± 3.4	0.645
Success rate (%)	24 (96%)	25 (100%)	0.500
Needle pass number	2.16 ± 0.37	4.96 ± 1.43	<0.001*
Paresthesia (%)	0 (0 %)	8 (32%)	<0.001*

necessary for the injected anesthetics to show the effect of the nerve block.

Our study showed fewer needle passes (Table 2) in the PPV group (2.16 ± 0.37) than in the PN group (4.96 ± 1.43). Tran *et al.* [12] reported that more injections were followed by more needle passes (two injections, 4.0 ± 1.6; three injections, 5.2 ± 1.7; 4 injections, 6.0 ± 2.8). Bernucci *et al.* [13] reported similar results (PPV group, 3.5 ± 1; PN group, 8.2 ± 2.2). Our method showed fewer needle passes in the perivascular approach after omitting the separated MC nerve block, compared with other studies. Additional injections increase the procedure time and patient discomfort. The selection of a method with fewer needle passes would be appropriate if the results were similar.

Our study showed one failed block in the PPV group and the patient needed general anesthesia (success rate: PPV group, 96%; PN group, 100%), which was similar to the rate in other studies [3, 14]. Cho *et al.* [6] reported several block failures when the large axillary veins were located between the injection site and nerves in a single-shot perivascular block. Although rare, 6-o'clock and 12-o'clock double injections or a selective perineural approach for anatomic variation may decrease this failure rate. We administered 1.5% mepivacaine with epinephrine 5 μg/mL and 8.4% sodium bicarbonate 0.1 mEq/mL. Carbonization of mepivacaine offers a quicker onset of more profound blockade in the axillary brachial plexus [15]. We performed a brachial plexus block in the operating room, and a faster onset of anesthesia was achieved. Disinfection and draping for surgery preparation took approximately 20 min following the block procedure, and we chose a 15-minute observation time and achieved surgical anesthesia within 15 min.

Sedation was performed using dexmedetomidine infusion, and additional adjuvants were not required to control surgical pain. We used 30 mL of local anesthetic solution. Bernucci *et al.* [13] used 24 mL, Tran *et al.* [12] used 28 mL, Imasogie *et al.* [16] used 30 mL, and Ambi *et al.* [17] used 36 mL. González *et al.* [10] reported a minimum effective volume of 2% lidocaine with epinephrine 5 μg/mL in 90% of patients for double-injection ultrasound-guided axillary block, 5.5 mL for MC nerve, and 23.5 mL for perivascular injection. Erdogmus *et al.* [9] reported that the volume of 0.5% bupivacaine could decrease by 2.5 mL per nerve for a total of 7.5 mL (radial, ulnar, median nerve block), but decreasing local anesthetic dose will increase onset time and early regression of the block effect. No local anesthetic-related complications were observed in our study.

No vascular punctures were observed in this study. Paresthesia was observed only in the PN group (32%). However, none of the patients complained of anesthesia-related complications. We were cautious during the procedure to ensure that the needle tip was visible at all times. Bernucci *et al.* [13] reported that the perivascular group showed 8% of paresthesia, 24% of vascular punctures and the perineural group showed 52% of paresthesia with no vascular punctures. Two experienced anesthesiologists performed the procedures. Well-trained needling skills and a careful approach may decrease vascular punctures and nerve injuries [18].

Our study has several limitations. The absence of post-anesthetic complications and the lack of differences in motor paralysis (although there were significant differences in sensory block) may be attributable to the small sample size. The duration of surgical anesthesia was not recorded. However, no patient complained of pain or discomfort during the surgery and the most prolonged surgery was 3 hours and 36 minutes in the PPV group. Moreover, the surgeons in our hospital wanted earlier postoperative sensory and motor exams after surgery, and they preferred a nerve block with mepivacaine over bupivacaine.

5. Conclusions

In conclusion, PPV axillary block constitutes a simpler alternative technique but is as effective as conventional PN axillary block. The PPV group showed a similar quality of surgical anesthesia 15 min after the anesthetic procedure and MC nerve was properly blocked. The PN group showed a faster onset time; however, the PPV group showed a shorter procedure time, and the total induction time was not significantly different. In addition, the PPV group showed fewer needle passes and fewer instances of paresthesia during the procedure without increasing the risk of vascular punctures. PPV axillary block can be a simple, safe, and effective regional technique for upper limb surgery. Further study is needed to confirm the effectiveness of this method to validate the effect on motor nerve paralysis and the effectiveness with other drugs.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

JS—designed the study, wrote the original draft of the manuscript, and reviewed and edited the manuscript. MAK—performed the statistical analysis, and reviewed and edited the manuscript. PO and TH—performed the anesthetic procedures and managed data.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This prospective, randomized, observer-blinded trial was approved by the Institutional Review Board (Dankook University IRB No. 2021-10-008). Written informed consent was obtained from the 50 patients who underwent elective hand and forearm surgery.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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