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Ultrasound-guided block of selective branches of the brachial plexus for vascular access surgery in the forearm: a preliminary report

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ABSTRACT

Purpose: The operative field for vascular access (VA) surgery in the forearm is on the volar surface, and motor nerve block is not necessary for regional anesthesia. Therefore, selective block of branches of the brachial plexus may be a more efficient anesthesia technique.

Methods: Individual nerve blocks in the axillary brachial plexus and selective blocks of the musculocutaneous and medial antebrachial cutaneous nerves in the upper arm were performed using low doses and concentrations of a local anesthetic mixture of lidocaine and ropivacaine under ultrasound (US) guidance in patients undergoing VA surgery in the forearm. The targeted nerves were identified by continuous US tracing along the upper arm to the axilla in a short-axis view. We performed three VA surgeries in the forearm using an axillary brachial plexus block and four using a selective two-nerve bock in the upper arm. We recorded any additional anesthetic requirement and evaluated intraoperative pain using the Wong-Baker Faces Pain Rating Scale (WBFRS; 0 = no pain; 10 = worst pain).

Results: All of the target nerve branches were clearly identified by US tracing. All patients had satisfactory intraoperative pain control (0 or 2 score on WBFRS). Four patients required small additional doses of local anesthetic.

Conclusions: US-guided block of individual branches of the brachial plexus at the axilla achieved effective anesthesia using small amounts of local anesthetic. An advanced selective nerve block in the upper arm allows minimum necessary anesthesia and provides safe and efficient analgesia for VA surgery in the forearm.

Keywords: Arteriovenous fistula, Arteriovenous graft, Brachial plexus block, Selective nerve block, Ultrasound, Vascular access

Introduction

Ultrasound (US)-guided brachial plexus block (BPB) is the preferred method of regional anesthesia for vascular access (VA) procedures in the upper limb. Ideally, it provides effective anesthesia and adequate analgesia with an appropriate duration of action. US-guided BPB is used in patients undergoing arteriovenous graft (AVG) implantation and those undergoing surgeries requiring a wide incision, such as removal of an infected graft, as well as for procedures that use an above-elbow tourniquet for hemostatic control of high-flow fistulas and for percutaneous transluminal angioplasty for refractory strictures (1, 2). An axillary approach to BPB provides a suitable extent of anesthesia for surgical and percutaneous VA procedures in the forearm while limiting the risks of pneumothorax and phrenic nerve paresis that are associated with infra- and supraclavicular approaches (3). Because VA surgery in the forearm is performed on the volar surface and mainly involves skin, subcutaneous tissue, fascia, and vessels, a motor nerve block, such as that provided by complete axillary BPB, is usually not necessary.

Recent progress in US technology has made it possible to distinguish the individual branches of the brachial plexus in the axillary fossa (4, 5). US-guided BPB with multiple needle insertions around the median, ulnar, and radial nerves and around the musculocutaneous nerve (MCN), which terminates as a

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sensory nerve innervating the anterolateral forearm, is now regarded as a useful form of axillary BPB (3). However, the medial antebrachial cutaneous nerve (MACN), which is a peripheral sensory nerve that innervates the anteromedial portion of the forearm, and is one of the intended targets of an axillary BPB, can be difficult to identify in the axilla. Recent anatomical studies of the brachial cutaneous nerves have shown that the MACN can be identified by using the US probe to trace its course up and down along the upper arm (6, 7), and Nakanishi et al have recently reported successful US-guided selective sensory nerve block for forearm tendon surgery (8).

Here, we describe a method for US tracing of the MACN, ulnar nerve, radial nerve, median nerve, and MCN using a short-axis view along the upper arm that allows accurate identification of the nerves for an axillary BPB. On the basis of these procedures, we evaluated the anesthetic and analgesic efficacy of selective nerve block of the MCN and MACN in the upper arm in patients undergoing VA surgery in the forearm.

Methods

Patient selection and vascular access operations in the forearm

Seven patients, who had been considered to have operative indications of VA surgery with prosthetic graft implantation or wide skin incision in the forearm by preoperative US-guided evaluation of vessels in the ipsilateral upper limb, were enrolled between March and August 2015 (Tab. I). All patients gave written informed consent for all procedures in the study. Initially, three patients underwent AVG with an axillary BPB with individual nerve identification by the US-tracing method described later. In the next phase, four patients had a selective MCN and MACN block in the upper arm under US guidance for surgeries including AVG, a transposed radio-basilic arteriovenous fistula (AFV), and cephalobrachial venovenous grafts with and without strictureplasty of the cephalic vein for the repair of radio-cephalic AVFs. AVGs were implanted in a loop configuration between the brachial or radial artery and the basilic vein proximal to the elbow or the median cubital vein in the antecubital fossa, as previously described (9). All VA operations were performed by a single surgeon with more than 15 years of experience in VA surgery, who also performed the US-guided anesthesia. The surgeon had performed 103 axillary BPBs by employing perivascular (around the brachial artery [BA]) and perineural injections of local anesthetic using the out-of-plane method and 29 supraclavicular BPBs in an in-plane method in VA surgery in the upper limb for 3 years as the basis of this feasibility study. Operations commenced between 15 and 20 minutes after the completion of the nerve blocks, without an analgesia onset-conscious waiting time. If the patients felt pain on pinprick over the area of the planned skin incision, at skin incision after a painless pinprick test or on incision of the fascia over the vessels, an additional subcutaneous or subfascial dose of 1% lidocaine was given. Patients with hemiplegia caused by cerebral apoplexy and dementia, and those who required intraoperative sedation were excluded.

Continuous ultrasound tracing procedure

We used a linear 5- to 18-MHz transducer for real-time US guidance (HI VISION Avius: Hitachi Aloka Medical, Ltd, Tokyo, Japan). All nerves were mainly scanned in a short-axis view

TABLE I - Results of vascular access surgery in the forearm using ultrasound-guided individual and selective nerve block at the axilla and in the upper arm

Case	Gender	Age	Side of VA	Operation	Nerve block	LA mixture for nerve block			Additional LA	Site of additional LA	WBFRS	PBET (hours)
						1% Lidocaine (mL)	0.75% Ropivacaine (mL)	Saline (mL)	1% Lidocaine (mL)			
No.1	Male	74	Left	AVG	Axillary BP	10	5	5	3.0	Skin above the elbow	2	7.5
No.2	Male	61	Left	AVG	Axillary BP	10	5	5	0	-	0	10.0
No.3	Female	74	Left	AVG	Axillary BP	10	5	5	0	-	0	12.5
No.4	Male	83	Left	TRBAVF	MCN, MACN	5	5	0	0	-	0	9.0
No.5	Female	48	Left	AVG	MCN, MACN	5	5	0	0.5	Antecubital fascia	2	8.0
No.6	Male	75	Left	CBVVG Stricure-plasty	MCN, MACN	5	5	0	0.5	Wrist SBRN	2	12.0
No.7	Male	63	right	CBVVG	MCN, MACN	5	5	0	1.0	Antecubital separated CV	2	9.5

AVG = arteriovenous graft; BP = brachial plexus; CBVVG = cephalobrachial venovenous graft; CV = cephalic vein; LA = local anesthetic; MCN = musculocutaneous nerve; MACN = medial antebrachial cutaneous nerve; PBET = post-blockade effect time; SBRN = superficial branch of the radial nerve; TRBAVF = transposed radio-basilic arteriovenous fistula; VA = vascular access; WBFRS = Wong-Baker faces pain rating scale.

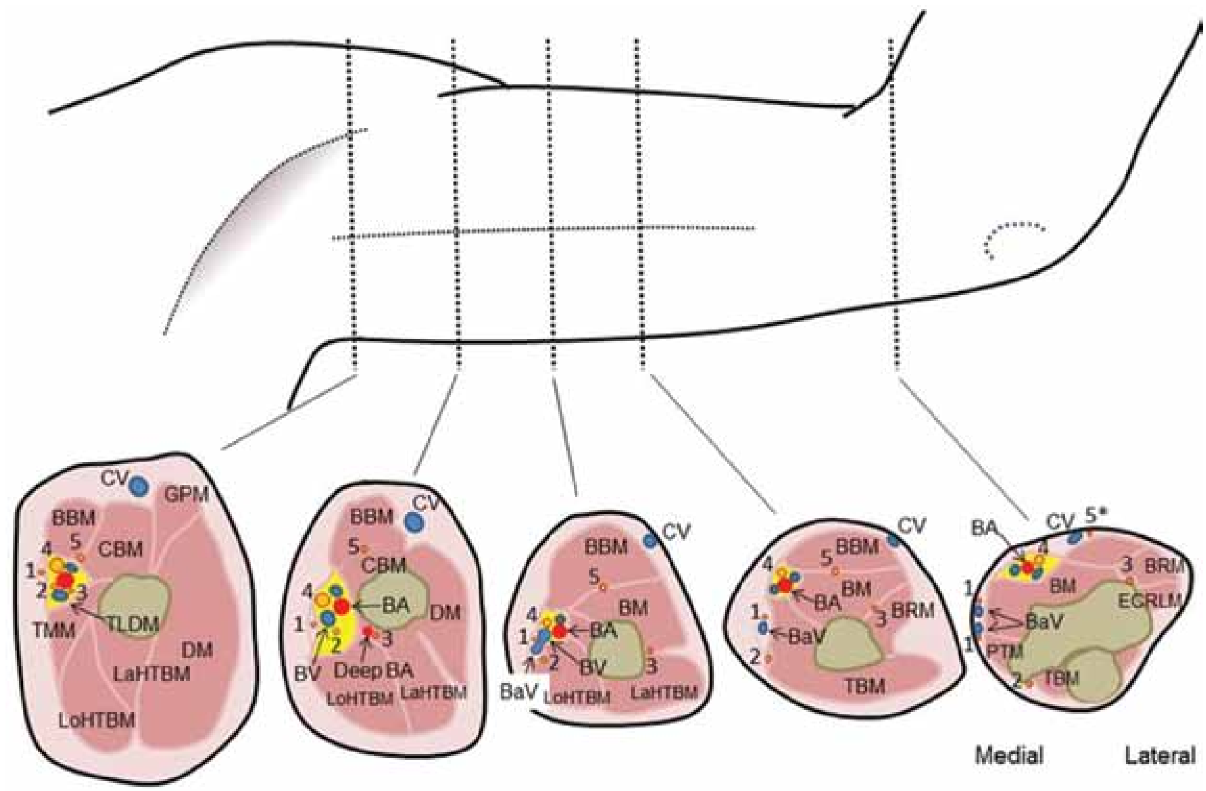

Fig. 1 - Cross-sectional views of the anatomical locations of the targeted nerves in the upper arm from the elbow to the axillary fossa. The MACN (1) runs adjacent to the BaV, passes deeply through the brachial fascia and past the junction of the BaV and BV, tracks proximally along the BV and is positioned in the median superficial side of the axilla over the neurovascular bundle. The ulnar nerve (2) runs upward from the medial side to near the BA and is positioned at the anteromedial side of the BA in the bundle at the axilla. The radial nerve (3) runs parallel to the deep BA along the inner side of the LoHTBM proximally and is located at the posteromedial site of the BA just above the TLDM at the axilla. The median nerve (4) runs along the BA and is positioned at the anterolateral side of the BA. The MCN (5), which bifurcates distally to the lateral antebrachial cutaneous nerve (5*) along the CV in the cubital fossa, is positioned apart from the BA between the BBM and the CBM. BA = brachial artery; BaV = basilic vein; BBM = biceps brachii muscle; BM = brachial muscle; BRM = brachioradial muscle; BV = brachial vein; CBM = coracobrachial muscle; CV = cephalic vein; DM = deltoid muscle; ECRLM = extensor carpi radialis longus muscle; GPM = greater pectoral muscle; LaHTBM = lateral head of the triceps brachii muscle; LoHTBM = long head of the triceps brachii muscle; MACN = medial antebrachial cutaneous nerve; MCN = musculocutaneous nerve; PTM = pronator teres muscle; TBM = triceps brachii muscle; TMM = eres major muscle; TLDM = tendon of latissimus dorsi muscle.

along the upper arm toward the axillary fossa using continuous US tracing as described in previous studies (4, 5, 8). Figure 1 shows the anatomical locations of the targeted nerves in terms of their course along the upper arm.

The medial antebrachial cutaneous nerve

The MACN, which is the most difficult nerve to identify at the axilla, runs subcutaneously upwards from the cubital fossa in a separate neurovascular sheath, alongside the basilic vein (8). It was visualized by US as a small aggregate of a few hypoechoic circles. It passed deeply through the brachial fascia in the upper arm, and after the basilic vein joined the brachial vein (BV), it ran proximally along the BV and was positioned at the median superficial side of the axilla above the neurovascular bundle containing the BA, the BV, and the ulnar, radial, and median nerves. The supplementary video shows a representative continuous US tracing of the MACN along the upper arm to the axillary fossa (see Video 1, available online as supplementary material at www.vascular-access.info). The video was produced by combining US and anatomical images (MeAV Anatomie, Okayama University and the Panasonic Corporation, Osaka, Japan) (10).

The ulnar nerve

Continuous US tracing clearly showed the ulnar nerve as an aggregate of a few hypoechoic circles at the ulnar groove in the cubital region. The ulnar nerve runs upward from the medial side to the area near the BA in the upper arm and is positioned at the anteromedial side of the BA in the axillary neurovascular bundle.

The radial nerve

The radial nerve is located in a posteromedial position relative to the BA in the axilla and runs peripherally along the deep BA to the back of the humerus. The deep BA and

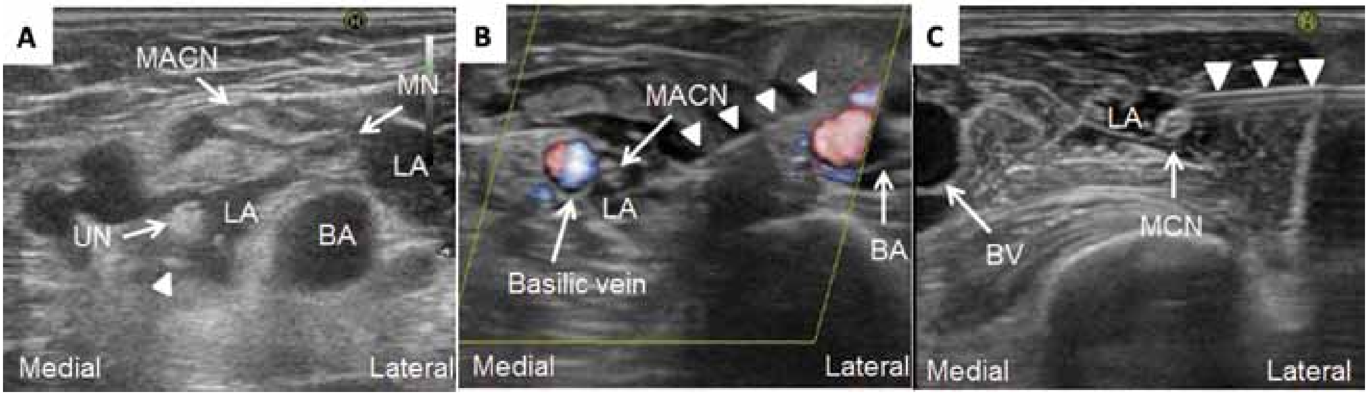

Fig. 2 - Real-time ultrasound-guided visualization of individual and selective nerves and injection of local anesthetic. Jiggling of the needle and hydrolocalization were helpful for definite visualization of the needle tip during the out-of-plane approach at the axilla (**A**). The tip of the needle was visible as a hyperechoic dot (A, arrowhead). The MACN along the basilic vein was blocked at the mid-upper arm and the MCN was blocked near the axilla (**B** and **C**). The interface of the needle shaft (B and C, arrowheads) and the nerves were visible along the long axis of the probe during the in-plane approach, and a donut sign (LA, B and C) was seen during infiltration of the local anesthetic. BA = brachial artery; BV = brachial vein; LA = local anesthetic; MN = median nerve; MACN = medial antebrachial cutaneous nerve; MCN = musculocutaneous nerve; UN = ulnar nerve.

the radial nerve run side-by-side along the inner side of the long head of the triceps brachii muscle at a slightly more peripheral and medial site of the upper arm near the axillary fossa. These structures could be followed proximally to the branching point of the deep BA from the BA. As we approximated the axillary fossa, only the nerve was visible as a round low-echo structure posteromedial to the BA, just above the tendon of latissimus dorsi.

The median nerve

The median nerve was easily visualized in the axilla at the anterolateral side of the BA as a hypo-echoic core or honeycomb image. Its course along the BA to the cubital fossa was briefly observed.

The musculocutaneous nerve

The MCN, which is positioned apart from the BA between the biceps brachii muscle and the coracobrachial [this is usually referred to as the coracobrachialis muscle] muscle, was easily identified in the axilla as a hypo-echoic core surrounded by hyper-echoic ring. It courses distally and more deeply as a small low-echoic circle between the biceps brachii muscle and the brachial muscle, arising subcutaneously through the fascia close to and along the course of the cephalic vein and bifurcating to the lateral antebrachial cutaneous nerve in the cubital fossa, and meanwhile, moving proximally closer to the axillary artery at the axillary fossa (6, 8).

Ultrasound-guided brachial plexus block by the axillary approach: out-of-plane method

The radial, ulnar, and median nerves and the MACN and MCN were targeted for BPB in the axilla above the latissimus dorsi tendon, and a local anesthetic mixture of short-acting 1% lidocaine (10 mL) and long-acting 0.75% ropivacaine (5 mL) with saline 5 mL was administered totally. The linear probe was placed in a transverse plane at the axilla with color Doppler scan. The five targeted nerves were identified by the methods described above. In patients with previous dialysis fistulas, the BA and the BVs in the upper arm and axillary fossa were remarkably dilated, and out-of-plane insertion using a fine 25-gauge injection needle (JMS Co., Ltd. Tokyo, Japan) was the preferred approach to the narrow perineural space surrounded by the dilated vessels in the axillary fossa. The tip of the fine needle was visible as a hyperechoic dot. Gently jiggling the needle was useful for definite visualization of the position of the needle tip, as was hydrolocalization, in which repeated injection of small amounts of anesthetic solution created an expanding echo-free zone that made the needle tip clearly visible (11, 12). Once precise location of the needle tip was confirmed, the area around the MCN was infiltrated with 4 mL of the local anesthetic solution, after which each of the other four nerves was blocked with 4 mL of local anesthetic injected from superficial-to-deep in the area around the BA, which produced a honeycomb appearance on US (Fig. 2A). Two or three skin punctures, one for the MCN and the others for the other four nerves in the axillary BPB, were needed. Meticulous positioning of the needle tip, visible accumulation of local anesthetic during injection, gentle negative aspiration, and awareness of high injection pressure were essential aspects of prevention of intravascular and intra-nerve fascicular injection.

Ultrasound-guided selective peripheral nerve block in the upper arm: in-plane method

The MCN and MACN were targeted for selective block in the upper-arm. A local anesthetic mixture of 1% lidocaine, 5 mL, and 0.75% ropivacaine, 5 mL, half of which was infiltrated around each nerve, was administered using an in-plane method with a 22-gauge short-beveled 5 cm nerve block needle (Plexufix®; B. Braun Melsungen AG, Melsungen, Germany). The dose of local anesthetic for one nerve was 0.5 mL more of 1% lidocaine and 1.5 mL more of 0.75% ropivacaine, compared to that used for axillary BPB with individual nerve identification. The MCN was blocked in the upper arm near the axilla. The MACN was blocked at the mid-upper arm, because the median nerve located near the MACN could be also blocked at the axilla. The entire passing needle could be seen along the long axis of the probe and the local anesthetic was infiltrated around the nerves while observing the hypo-echoic donut sign (Fig. 2B, C).

Assessment of ultrasound-guided nerve blocks

Additional local anesthetic requirement, intraoperative pain severity, and duration of post-blockade effect (interval between completion of the nerve block and return of motor and sensory perception, which was defined as no difference between the ipsilateral and contralateral arm) were assessed. We used the Wong-Baker FACES® Pain Rating Scale (WBFRS) to assess pain severity (13), which uses faces from happy to tearful, rating pain in six stages from 0 (no pain) to 10 (worst pain imaginable), to express the severity of pain. The WBFRS is often used for pediatric pain evaluation. We chose it because it is clear and easy to understand, which we thought would be helpful for elderly or mildly confused patients. Pain evaluations were performed during the immediate post-operative period.

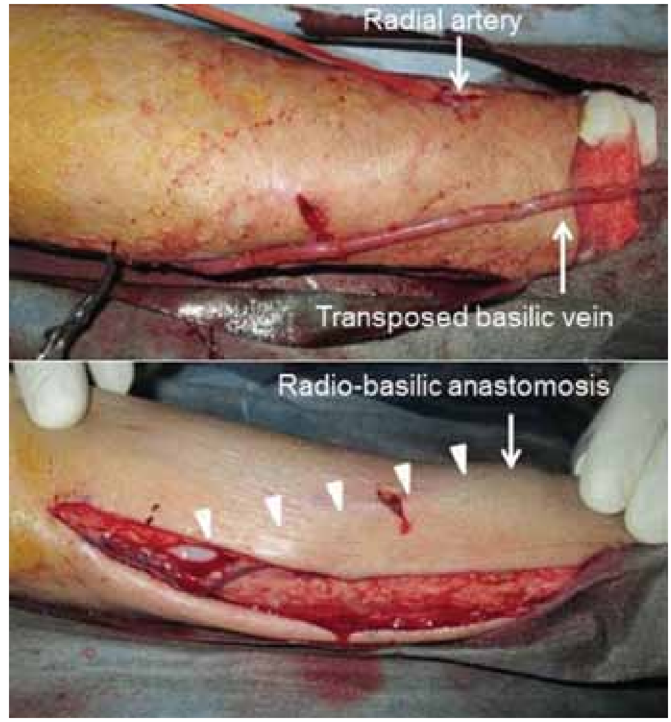

Fig. 3 - Transposed radio-basilic AVF creation (Patient 4) using selective ultrasound-guided block of the musculocutaneous nerve and the medial antebrachial cutaneous nerve. A wide skin incision was made in the anteromedial side of the forearm and the basilic vein was exposed and detached. The freed basilic vein was transposed subcutaneously (bottom panel, arrowheads) and anastomosed to the radial artery at the wrist. AVF = arteriovenous fistula; MACN = medial antebrachial cutaneous nerve; MCN = musculocutaneous nerve.

Results

The results are presented in detail in Table I. The individual targeted nerves were identified by US tracing in all patients. WBFRS scores indicated that all patients had satisfactory pain control. One patient in the axillary BPB group required additional local anesthetic at the skin incision in the medial area of the upper arm, through which the basilic vein was isolated for the anastomosis to the graft. Except for one patient (No. 4 in Tab. I, Fig. 3), three patients who had selective block of the MCN and MACN required small doses of additional local anesthesia during antecubital fascial incision, manipulation of the superficial radial nerve, and separation of the cephalic run-off vein. No patient required additional local anesthesia at the skin incision sites, and all doses of additional anesthesia that were required, were minimal. The post-blockade effect time of selective block ranged from 8.0 to 12.0 hours including minimum hyposthenia of upper arm flexor as a motor block. No patient had signs of systemic anesthetic toxicity or neurologic symptoms, and in all cases the new or repaired accesses were used for hemodialysis without complication.

Discussion

US-guided BPB has become a useful anesthesia method for VA surgery. BPB has anti-sympathetic effects that cause significant vasodilatation and subsequent increased blood flow in the upper limb, which may prevent early postoperative thrombosis and maintain the patency of AVFs and AVGs (14-19).

We have mainly used US-guided BPB for intraoperative analgesia in AVG-related procedures, including graft implantation and removal of infected grafts. Because these surgeries are typically finished within a few hours (at most), and because patients usually do not experience severe pain or require long-acting postoperative analgesia, we have focused on elements of patient satisfaction including quicker onset and sufficient intraoperative effect of anesthesia as well as rapid postoperative resolution of the nerve block. Perineural injection of local anesthetic during US-guided axillary BPB has resulted in more rapid onset than perivascular injection (20), and the effective volume and concentration of local anesthetic can be reduced by perineural injection (21, 22).

Based on these findings, we first performed US-guided axillary BPB for patients undergoing VA surgery in the forearm. Each nerve was identified correctly by continuous US tracing, and we used a lower dose and concentration of local anesthetic compared to previous reports (14, 17, 18). Christophe et al (5) have assessed the topographical variations of the nerves of the brachial plexus in the axilla in detail, and their work contributed substantially to our ability to identify the radial, ulnar, and median nerves, as well as the MCN, during the clinical performance of US-guided axillary BPB. However, the MACN, which provides sensory innervation to a large part of the anteromedial portion of the forearm, has not previously been studied with reference to the detailed anatomical variations at the axillary fossa (1, 23, 24), although anatomical variations of small cutaneous nerves in the upper limb have been investigated in terms of avoiding venipuncture-induced nerve injuries (25, 26). Some anatomical studies have reported that peripheral cutaneous nerves, including the MACN and the lateral antebrachial cutaneous nerve, which is the final branch arising from the MCN, could be directly visualized by US, and that the MACN is located in a lateral position relative to and parallel to the basilic vein *in vivo* (6, 7, 27).

In our study, accurate identification of individual nerves of the brachial plexus and infiltration of local anesthetic around each one of them during axillary BPB led to satisfactory analgesia, even at low doses and concentrations of local anesthetic, during surgical VA procedures in the forearm. No additional local anesthesia was required in the forearm, without analgesia onset-conscious waiting time; however, despite local anesthetic mixture containing a low dose of long-acting ropivacaine, the duration of the post-blockade effect was as long as up to 12.5 hours. In one patient, additional local anesthesia was needed around the skin incision in the medial upper arm above the elbow. This area is considered to be at the innervated verge of the MACN and two other nerves, i.e, the medial brachial cutaneous and intercostobrachial nerves, neither of which can be blocked at the axillary level (24).

The actual results of axillary BPB under US-guided individual nerve identification provided us with a useful clue as to the resolution of the postoperative long motor blockade of the whole upper limb, even with quick-onset and adequate intraoperative analgesia. The selective block of the MACN and MCN could minimize block area, especially motor perception, in the upper limb, using almost the same low dose of local anesthetic mixture per nerve as axillary BPB. Nakanishi et al (8) recently reported successful selective sensory nerve block in patients who were undergoing forearm tendon reconstruction, which allowed the surgeons to monitor active muscle motion continuously during the procedure. On the basis of their pioneering approach, we applied US-guided selective peripheral nerve block in the upper arm for VA surgeries in the forearm. The MACN, which provides sensory innervation to the skin of the anteromedial forearm and the MCN, which provides sensory innervation to the skin of the anterolateral forearm and motor innervation to the upper arm flexor muscles, were selectively blocked. Satisfactory results were obtained with sufficient intraoperative analgesia even with small amounts of local anesthetic, and there was minimum postoperative effect of the motor block in the area innervated by the MCN. Furthermore, no patient required additional local anesthetic at skin incision sites. This confirmed the feasibility of US-guided perineural infiltration of local anesthetic around peripheral nerves that are isolated from vessels and surrounded by small amounts of fatty tissue. Three patients who received selective MCN and MACN block needed small amounts of additional local anesthetic during incision of the fascia, manipulation of the radial nerve, and detachment of the cephalic runoff vein. Additional sub-fascial anesthesia may be required, as the detailed innervation of the forearm fascia has not been elucidated (8).

Finally, in comparison with total axillary BPB, which is considered safer for VA surgery than general anesthesia among patients suffering from end-stage renal disease (1), selective peripheral anesthesia that limits the extent of the nerve block and preserves sensation in the hand may help prevent intraoperative injury of unblocked peripheral superficial nerves. Additionally, it allows, in conscious patients, real-time assessment for signs of acute VA-associated steal syndrome and ischemic monomelic neuropathy, both of which could occur soon after AVF and AVG procedures. Meanwhile, unexpected intraoperative procedural changes to the upper arm surgery may force surgeons to add local anesthesia, supraclavicular BPB, or general anesthesia, keeping the patients on spontaneous breathing, for expanded analgesia and anesthesia, although preoperative ultrasonographic planning of VA surgery in the upper limb could reduce such cases.

We conclude that US-guided selective nerve block in the upper arm, derived from the technique of continuous US tracing of nerves branching from axillary BP, can provide safe and efficient anesthesia, even at a low anesthetic dose and concentration during VA surgery in the forearm.

Disclosures

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