Materials and Methods

We enrolled eight consecutive patients who underwent tendon transfer or tendon graft surgery at the forearm in our department from February 2013 to April 2014. Three of the eight patients underwent tendon graft or tendon transfer for flexor tendon injuries in zone 4 or 5, three underwent opponensplasty of the thumb for carpal tunnel syndrome, and two underwent tendon transfer according to Brand’s procedure for posterior interosseous nerve palsy. Each patient underwent ultrasound-guided anesthetic injection 1 hour before surgery. The peripheral nerves in the upper extremities were examined using an ultrasound unit (LOGIQ P6; General Electric, Fairfield, CT) with a 16-MHz linear matrix probe. A 23-gauge, 70-mm needle was used for injection. All cutaneous nerves were carefully blocked using the in-plane method of ultrasound guidance. We selected one of several injection patterns depending on the operative procedure performed. The anesthetic method used for each procedure is described below.

Opponensplasty

Upper arm. First, we blocked the cutaneous sensory nerves of the upper arm (musculocutaneous nerve, medial cutaneous nerve of the forearm, and posterior
cutaneous nerve of the forearm) using approximately 2 mL of 0.750% ropivacaine for each nerve.

**Middle forearm.** Second, we blocked the superficial branch of the radial nerve in the middle of the forearm. To provide analgesia to the fascia of the forearm, we injected 5 to 10 mL of 0.375% ropivacaine in the subfascial layer between the flexor muscle belly and the forearm fascia.

**Distal forearm.** Third, we blocked the superficial palmar branch of the median and ulnar nerves approximately 3 cm proximal to the wrist joint using approximately 2 mL of 0.750% ropivacaine for each nerve.

**Flexor tendon reconstruction at the forearm**

In addition to the anesthesia for opponensplasty indicated above, we blocked additional nerves as described below;

**Distal forearm.** We injected approximately 3 mL of 0.750% ropivacaine into the anterior interosseous nerve for sensory block of the periosteum in the distal one-third of the forearm for an additional surgical procedure, which included spur resection at the volar surface of the distal radius.
Brand's procedure

In addition to the anesthesia for flexor tendon reconstruction indicated above, we blocked additional nerves as described below;

Middle forearm. We blocked the anterior and posterior interosseous nerve to achieve sensory block of the interosseous membrane using approximately 3 mL of 0.750% ropivacaine.

Distal forearm. We injected approximately 2 mL of 0.750% ropivacaine into the dorsal branch of the ulnar nerve in the distal one-third of the forearm.

In this study, we evaluated the total amount of local anesthetic used for each patient; the active motion of the forearm muscles, which are the donor muscles of the reconstructed tendons; the presence or absence of pain during each surgery and the amount of additional local anesthetic, if required; and the presence or absence of adverse events.
Results

The total amount of preoperatively injected ropivacaine was 193 ± 23 mg (37 ± 6 mL) (Table 1). We confirmed active motion of the donor muscle in seven of the eight patients. In one case, the expected active motion of flexor pollicis longus was not observed during surgery. In this case, local anesthetic (0.75% ropivacaine 3 mL) injected for the superficial branch of the median nerve may have spread proximally along the median nerve, because the blocking site is too proximally located.

Two of the 8 patients complained of pain in the surgical site during the surgery. Then, 2 mL and 3 mL of 1% lidocaine was added by local infiltration in these cases. No patient showed particular adverse event.
Discussion

This study has demonstrated the effectiveness of ultrasound-guided selective sensory nerve block for wide-awake forearm tendon transfer. Although two patients required additional local anesthesia (2–3 ml of 1% lidocaine), complete analgesia was achieved in the other six patients during the surgery. The expected active motion of the flexor pollicis longus was not observed in one patient who underwent surgical tendon reconstruction. We consider that this failure can be avoided by careful selection of the block site. The total amount of preoperatively injected ropivacaine ranged from 154 to 225 mg, which is much smaller than that reported by Lalonde et al.\textsuperscript{1} No adverse events such as nerve injury or local anesthetic systemic toxicity were observed in the current series. We consider ultrasound-guided selective sensory nerve block to be a potentially promising technique.

This selective sensory nerve block procedure involves three separate layers that are blocked to successfully achieve analgesia before forearm surgery. First, the forearm derma is innervated by seven cutaneous nerves: the medial, lateral, and posterior cutaneous nerves of the forearm; the dorsal branches of the radial and ulnar nerves; and the palmar superficial branches of the median and ulnar nerves. Because the cutaneous
branches of these nerves overlap one another, it is necessary to block all branches
coursing to the area of the surgical incision. These fine peripheral nerves can be clearly
observed with a high-frequency ultrasound probe. We successfully blocked each of
these nerves individually with approximately 2 mL of 0.75% ropivacaine under
ultrasound guidance. Second, we blocked the forearm fascia by injecting the subfascial
layer. The details regarding the innervation of the forearm fascia have not been well
clarified. We consider this subfascial block in the middle third of the forearm to be
adequate for achieving analgesia during creation of the fascial incision6. Analgesia of
the interosseous membrane was achieved by blocking the anterior and posterior
interosseous nerves at the middle aspect of the forearm. This block site should be
located distal to the branching site of the motor nerves8. Thus, it is possible to avoid
motor nerve block by performance of sequential, selective sensory nerve blocks.

Although the selective sensory nerve block technique described herein is a technically
demanding and complicated procedure, we consider that the limited doses of anesthetic
agents required allow for the safe and effective performance of forearm tendon surgery.

Further clinical trials are warranted to design a more accurate and reliable approach for
wide-awake surgery.
In conclusion, ultrasound-guided selective sensory nerve block is a promising procedure for wide-awake forearm tendon surgery. The total amount of local anesthetic can be reduced with the use of ultrasound-guided injection to each sensory nerve to the skin, subcutaneous tissue, fascia, and interosseous membrane of the forearm.


<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Sex</th>
<th>Side</th>
<th>Surgery</th>
<th>Block at the Upper Arm</th>
<th>Block at the Forearm</th>
<th>Subfascial Block</th>
<th>Total Amount of Ropivacaine (mg)</th>
<th>Additional Block during the Surgery</th>
<th>Motion of the Muscle during the Surgery</th>
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<tbody>
<tr>
<td>1</td>
<td>69</td>
<td>F</td>
<td>Left</td>
<td>Tendon Reconstruction/Tendon Injury</td>
<td>MCN, MCNF</td>
<td>SBRN, SPBMUN, AIN</td>
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<td>2</td>
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<td>M</td>
<td>Left</td>
<td>MCN, MCNF</td>
<td>MCN, MCNF</td>
<td>SBRN, SPBMUN, AIN</td>
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<td>Opponensplasty/CTS</td>
<td>MCN, MCNF</td>
<td>SBRN, VBMUN</td>
<td>SFBVSF, SFBDsf</td>
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<td>Opponensplasty/CTS</td>
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<td>SBRN, VBMUN</td>
<td>SFBVSF, SFBDsf</td>
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<td>none</td>
<td>successful</td>
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<td>Opponensplasty/CTS</td>
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<td>SBRN, SPBMUN, DBUN, AIN, PIN</td>
<td>SFBVSF, SFBDsf</td>
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<td>F</td>
<td>Left</td>
<td>Brand's procedure/Radial Nerve Palsy</td>
<td>MCN, MCNF, PCNF</td>
<td>SBRN, SPBMUN, DBUN, AIN, PIN</td>
<td>SFBVSF, SFBDsf</td>
<td>176</td>
<td>1% Lidocaine 3 mL</td>
<td>successful</td>
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</table>

Table 1. Summary of patients and anesthesia

MCN: musculocutaneous nerve  MCNF: medial cutaneous nerve of the forearm
PCNF: posterior cutaneous nerve of the forearm
SBRN: superficial branch of the radial nerve  SPBMUN: superficial palmer branch of the median and ulnar nerve
DBUN: dorsal branch of the ulnar nerve  AIN: anterior interosseous nerve  PIN: posterior interosseous nerve
SFBVSF: subfascial block of volar side of the forearm  SFBDsf: subfascial block of dorsal side of the forearm
Figure 1: A) Infiltration of local anesthetic based on the anatomical landmark. Large amount of local anesthetic is required.

b) Selective sensory nerve block for Brands procedure.