Educational and clinical aspects of peripheral nerve blockade
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Effect of local anesthetic volume (15 vs 40 ml) on the duration of ultrasound-guided single shot axillary brachial plexus block
A prospective randomized, observer-blinded trial

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Abstract

Background and Objectives
One of the advantages of ultrasound-guided peripheral nerve block is that visualization of local anesthetic spread allows for a reduction in dose. However, little is known about the effect of dose reduction on sensory and motor block duration. The purpose of the present study was to compare the duration of sensory and motor axillary brachial plexus block (ABPB) with 15 or 40 mL mepivacaine 1.5%.

Methods
Thirty patients were randomly allocated to receive ultrasound-guided ABPB with either 15 (group 15 mL, n = 15) or 40 mL (group 40 mL, n = 15) mepivacaine 1.5%. Onset, efficacy, and duration of sensory and motor block were compared.

Results
Two patients in group 15 mL needed an additional rescue block before surgery and were excluded from subsequent analysis. The overall median duration of sensory and motor block was significantly shorter in group 15 mL (225 [148-265] min vs 271 [210-401] min and 217 [144-250] min vs 269 [210 - 401] min, respectively; p < 0.01). Duration of sensory and motor block of individual nerves was significantly shorter in group 15 mL (20%-40% reduction for sensory and 18%-37% for motor block). Time to first request of postoperative analgesia was also significantly reduced in group 15 mL (163 [SD, 39] vs 235 [SD, 59] min, respectively, p < 0.05). There were no differences in the other block characteristics.

Conclusion
In ABPB with mepivacaine 1.5%, reducing the dose from 40 mL to 15 mL (62.5%) shortens the overall duration of sensory and motor block by approximately 17% to 19%, reduces sensory and motor block duration of individual nerves by 18% to 40%, and decreases the time to first request of postoperative analgesia by approximately 30%.
Effect of local anesthetic volume (15 vs 40 ml) on the duration of ultrasound-guided single shot axillary brachial plexus block
A prospective randomized, observer-blinded trial

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Results
Introduction

Peripheral nerve block as an anesthetic technique plays an important role in modern regional anesthesia. The most important prerequisites for the use of peripheral regional anesthesia in daily clinical practice are success rate and safety. Ultrasound guidance shortens block performance time, reduces the number of needle insertions, and shortens the block onset time.1 Recent publications illustrate that the volume of local anesthetic can be significantly reduced with the use of ultrasound.2–10 Axillary brachial plexus block (ABPB) is widely used to provide anesthesia for surgery of the forearm, wrist, and hand. The procedure is relatively safe, and complications are uncommon.11 Before the introduction of ultrasound, volumes of 40 mL or more were commonly used.12 Recent research has focused on reducing the volume necessary to establish adequate ABPB. Volumes of 5 mL per nerve13 or even as low as 1 mL lidocaine 2% per nerve6 have been reported to achieve successful ABPB. However, the effect of dose reduction on block duration remains unknown.

The purpose of the present study was to evaluate the effect of the volume of mepivacaine 1.5% on the duration of sensory and motor block in ultrasound-guided ABPB.

Materials and Methods

Patients

This prospective single-blinded, randomized study was approved by the Institutional Review Board Nijmegen and registered at http://www.trialregister.nl (NTR2371) before participant enrolment. Patients scheduled for a single-shot ABPB for hand, wrist, or forearm surgery were assessed for eligibility during the preoperative screening visit. Patients were informed about the study verbally and in writing, and written informed consent was obtained from all patients. The study was conducted at the Sint Maartenskliniek, Nijmegen, The Netherlands, between July 2010 and March 2011 in accordance with the Declaration of Helsinki and later revisions thereof, as well as ICH guidelines for Good Clinical Practice.

Eligible participants were adults 18 years or older with American Society of Anesthesiologists physical health classification I-III and a body weight greater than 50 kg. Exclusion criteria included contraindications for regional anesthesia (infection at the injection site, coagulopathy), known hypersensitivity to amide-type local anesthetics, known history of peripheral neuropathy, and known history of hepatic or renal insufficiency.
Anesthetic Procedure

All patients received paracetamol 1000 mg orally 3 times daily and meloxicam 15 mg orally once daily, starting on the morning of surgery. Additional postoperative pain treatment was provided upon patient request and consisted of oxycodone 10 mg orally 4 to 6 times daily.

Using a computer-generated sequence of random numbers and a sealed envelope technique, 30 patients were randomly allocated to receive ultrasound-guided ABPB with either 15 mL (group 15 mL, n = 15) or 40 mL (group 40 mL, n = 15) mepivacaine 1.5%. After establishing intravenous access and routine monitoring (electrocardiogram, non-invasive blood pressure, and peripheral oxygen saturation), ABPB was performed under ultrasound guidance (L12-5 linear probe connected to Philips HD11 XE; Philips, Eindhoven, The Netherlands) using a short-axis, in-plane technique. Blocks were performed under aseptic conditions using chlorhexidine skin preparation and sterile ultrasound probe covers (Flexasoft; Medicocare, Numandsorp, The Netherlands).

A 100-mm, 22-gauge, insulated, short-bevel needle (Stimuplex; B. Braun, Melsungen, Germany) was inserted laterally in the axilla. The needle was connected to a nerve stimulator (Stimuplex HNS 11; B. Braun) that was set to deliver 100 Nc (0.1 millisecond, 1 mA), only to facilitate identification of the individual nerves. After identifying the musculocutaneous, median, ulnar, and radial nerves, each nerve was blocked with either 10 mL (40 mL group) or 3 to 4 mL (15 mL group) mepivacaine 1.5%.

Time was designated t = 0 upon conclusion of the block procedure.

Clinical Assessments

In the first 30 min after injection of the local anesthetic solution, a blinded observer assessed the onset of sensory and motor block every 5 min. Sensory block of the medial antebrachial cutaneous, musculocutaneous, radial, median, and ulnar nerves was assessed by pinprick at specific sites (Table 1). Sensory block was scored on a 3-point scale as 0 = absent, 1 = partial, and 2 = complete.

At the same intervals, motor block of the musculocutaneous, radial, median, and ulnar nerves was assessed (Table 1) on a similar 3-point scale (0 = no, 1 = partial, and 2 = complete motor block). A complete overall sensory block was defined as a total score of 10; complete overall motor block was defined as a total score of 8. In case of insufficient analgesia at the surgical site at t = 30 min, an additional rescue block was placed in the block room, and the patient was excluded from further analysis.
Surgery was performed under regional anesthesia. In the case of patient discomfort or upon patient request, sedation was provided with propofol (25-60 µg/kg per minute) and remifentanil (0.01-0.05 µg/kg per minute). If sedation was insufficient for patient discomfort, patients were converted to general anesthesia. Upon arrival at the recovery room, offset of sensory and motor block was assessed by a blinded observer every 15 min in the same manner as preoperatively until full recovery. The primary outcome parameter was overall duration of sensory block. Overall duration of sensory block was defined as the time from $t = 0$ until the first postoperative measurement where total sensory score had returned to 0. Overall duration of motor block was defined similarly. Duration of sensory and motor block of individual nerves was defined as the time from $t = 0$ until the first postoperative measurement where the sensory and motor score for the individual nerve was 0. Secondary outcome parameters included overall duration of motor block, duration of sensory and motor block of individual nerves, block onset time, block efficacy, and time to first request for additional postoperative pain treatment (TTFR). Block onset time was defined as the time from $t = 0$ until the time sensory, respectively, motor score was maximal. Block efficacy during surgery was assessed as successful (no intraoperative sedation necessary), partially successful (intraoperative sedation necessary), or unsuccessful (conversion to general anesthesia). Time to first request for additional postoperative pain treatment was defined as the time interval from $t = 0$ until the time the first request for postoperative analgesia was made.

Sample Size and Statistical Analysis
The sample size calculation was based on the overall duration of sensory block. Robaux et al\textsuperscript{14} found a sensory duration of ABPB (with 40 mL mepivacaine 1.5%) of 183 (SD, 43) min. Based on these data, the sample size required to have a 90% probability of detecting a decrease in duration of 60 min (level of significance 0.05) was 12 patients per group using an unpaired t test. Compensating for dropout, we chose to include 15 patients per group. Analysis was per protocol. Data were analyzed using the GraphPad InStat v. 3.10 package (GraphPad Software Inc, San Diego, California). The Kolmogorov-Smirnov test was used for normality testing. Continuous, normally distributed data are presented as mean (SD), and non-normally distributed data as median (range). Statistical comparison between the groups was based on the Student t test for normally distributed data, and the Mann-Whitney U test for nonparametric comparisons. For comparisons within groups, normally distributed data were compared using the 1-way analysis of variance, and non-
normally distributed data using the Kruskal-Wallis test. Post hoc comparisons were made using Tukey-Kramer or Dunn multiple comparisons test as appropriate. Categorical data were compared using Fisher exact test. In the case where a parameter was normally one group and non-normally in the other group, the data are presented as median (range), and a nonparametric test as used for statistical comparison. All tests were 2-sided, and $p < 0.05$ was considered statistically significant.

**Results**

Thirty patients were included, 15 in each group. A flowchart of patients enrolled in this study is presented in Figure 1. In group 15 mL, 2 patients needed a rescue block before surgery because of incomplete block in the surgical area, compared with 0 patients in group 40 mL. These 2 patients were excluded from subsequent analysis. There were no significant differences in patient demographics between the 2 groups (Table 2). On 7 time points postoperatively, we were unable to obtain a measurement of sensory and motor blocks in 6 patients because of temporary patient unavailability. In 5 patients, these missing data did not affect the outcome parameters because sensory and motor blocks were still present at the next measurement. In 1 patient (group 40 mL), we missed 2 consecutive measurements during which both sensory and motor blocks had completely resolved. In this patient, we took the first time point following the missing data to calculate overall block duration; replacing this time point with the first time point where we were unable to obtain a measurement (30 min earlier) revealed that this did not significantly affect the results.

**Block Characteristics**

Thirty minutes after block placement, 7 of 13 patients in group 15 mL had a complete sensory block (maximum score of 10) versus 9 of 15 patients in group 40 mL (not statistically significant [NS]). Onset of complete sensory block was 21 (SD, 5) min in group 15 mL ($n = 7$) and 22 (SD, 6) min in group 40 mL ($n = 9$) (NS). After 30 min, motor block was complete (maximum score of 8) in 8 of 13 patients in group 15 mL versus 11 of 15 patients in group 40 mL (NS). Onset of complete motor block was 22 (SD, 8) min and 23 (SD, 7) min in group 15 mL ($n = 8$) and group 40 mL ($n = 11$), respectively (NS). There were no significant
differences between the groups in the onset times of sensory/motor block of individual nerves. Data on sensory and motor block scores of individual nerves are shown in Table 3.

The median overall duration of sensory block in group 40 mL was 271 (range, 210-401) min versus 225 (range, 148-265) min in group 15 mL ($p < 0.001$). The median overall duration of motor block was 269 (range, 210-401) min in group 40 mL versus 217 (range, 144-250) min in group 15 mL ($p < 0.001$) overall duration was largely determined by the duration of sensory and motor block of the ulnar nerve. In 10 of 13 patients in group 15 mL and 10 of 15 patients in group 40 mL, the ulnar nerve was among the last to recover. Within each group, there were no significant differences in the duration of sensory and motor block between the individual nerves. Between groups, the duration of both sensory and motor blocks for each individual nerve was significantly longer in group 40 mL. Data on overall and individual block characteristics are summarized in Table 4 and Figures 2-4.

Twelve patients, 6 in each group, requested additional postoperative analgesia. Time to first request for additional postoperative pain treatment was significantly shorter in group 15 mL (163 [SD, 39] min) as compared with group 40 mL (235 [SD, 59] min) ($P < 0.05$). Twenty-five patients underwent surgery without need for additional sedation. Three patients, 2 in group 15 mL and 1 patient in group 40 mL, needed sedation because of patient discomfort. None of the patients required conversion to general anesthesia.

### Sensory and Motor Testing

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Sensory test Site</th>
<th>Motor Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial antebrachial</td>
<td>-</td>
<td>Medial side</td>
</tr>
<tr>
<td>cutaneous forearm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Musculocutaneous</td>
<td>Lateral side forearm</td>
<td>Elbow flexion</td>
</tr>
<tr>
<td>Radial</td>
<td>Dorsum of hand</td>
<td>Wrist extension</td>
</tr>
<tr>
<td>Median</td>
<td>Ventral top of middle finger</td>
<td>Thumb opposition</td>
</tr>
<tr>
<td>Ulnar</td>
<td>Hypothenar eminence</td>
<td>Finger abduction</td>
</tr>
</tbody>
</table>

Table 1  Sensory and Motor Testing
Discussion

In the present investigation, a local anesthetic volume reduction of 60% resulted in an approximately 17% shorter overall sensory and 19% motor block duration and a reduction in TTFR of approximately 30%. Because overall duration is determined by the last nerve to recover, this parameter may underestimate the effect of a reduction in dose. Indeed, we found that the reduction in duration for individual nerves was larger, varying from 20% to 40% for sensory block and from 18% to 37% for motor block. The ulnar nerve was least affected by the

Consort flowchart

Figure 1  Flowchart of patients enrolled in the study.
reduction in dose; the 2 nerves most strongly affected were the medial antebibral cutaneous and musculocutaneous nerves. Duration of peripheral nerve block depends on several factors, such as the choice of local anesthetic, the site of injection, and the presence of adjuncts, for example, clonidine or epinephrine. Some studies in children indicate that the use of ultrasound guidance itself provides a longer duration of sensory blockade compared with nerve stimulation without ultrasound. The dose of local anesthetic administered when performing peripheral nerve block is determined by volume and concentration; the manner in which these parameters affect duration is controversial. In a study aimed to determine the minimum effective anesthetic volume for blocking the median and ulnar nerve with mepivacaine 1.5%, Ponrouch et al. found that the use of ultrasound as compared with nerve stimulation reduced the effective anesthetic volume by 50%. They also found a significant correlation between the volume of local anesthetic and the duration of sensory blockade, the correlation being higher with lower volumes. Similar findings were reported in a volunteer study designed to determine the ED99 volume of mepivacaine 1.5% for sciatic nerve block, showing a proportional relation between volume of local anesthetic per millimetre squared cross-sectional nerve area and duration of sensory block. In a study comparing low-volume (16 mL) ultrasound-guided ankle block with a conventional higher-volume (30 mL) landmark technique using ropivacaine 0.5%, Fredrickson et al. found that average postoperative pain was marginally higher in the low-

### Baseline Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Group 15mL (n = 13)</th>
<th>Group 40mL (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex, no. male/no. female</strong></td>
<td>5/8</td>
<td>4/11</td>
</tr>
<tr>
<td><strong>Age, y</strong></td>
<td>53 (16)</td>
<td>55 (9)</td>
</tr>
<tr>
<td><strong>Height, cm</strong></td>
<td>171 (9)</td>
<td>173 (8)</td>
</tr>
<tr>
<td><strong>Weight, kg</strong></td>
<td>76 (13)</td>
<td>78 (14)</td>
</tr>
<tr>
<td><strong>Body mass index, kg/m2</strong></td>
<td>25.8 (3.7)</td>
<td>25.8 (2.8)</td>
</tr>
<tr>
<td><strong>Duration of surgery, min</strong></td>
<td>23.2 (15.6)</td>
<td>21.5 (10.7)</td>
</tr>
</tbody>
</table>

Table 2

Group 15 mL: axillary brachial plexus block with 15 mL mepivacaine 1.5%.
Group 40 mL: axillary brachial plexus block with 40 mL mepivacaine 1.5%.
Values are numbers or mean (SD).
volume group. Although the authors did not measure block duration or the time to first request of postoperative analgesia directly, the results suggest a shorter duration of sensory block associated with the low-volume group. On the other hand, Serradell et al.\textsuperscript{20} compared the number of complete sensory blocks for different volumes (20, 28, 36 mL) of mepivacaine 1% in axillary block and found no differences in success rate, onset time, and duration of analgesia among the 3 groups. The results of the latter study suggest that 200 mg mepivacaine in a volume of 20 mL provides adequate axillary block and that increasing the volume/dose of mepivacaine to 280 or 360 mg does not result in a higher success rate or a longer duration of analgesia. Duration of analgesia reported by Serradell et al.\textsuperscript{20} was 231 (SD, 45) min in their group receiving axillary block with 200 mg mepivacaine in 20 mL. Interestingly, the TTFR in our group 40 mL (600 mg mepivacaine) was similar (235 [SD, 59] min), whereas the TTFR in our group 15 mL (225 mg mepivacaine) was considerably shorter. Although differences in methodology preclude making direct comparisons, these observations may indicate that the reduction in block duration seen in our study is caused by the reduction in volume from 40 mL to 15 mL rather than the

### Block Scores of Individual Nerves

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Group 15mL (n = 13)</th>
<th>Group 40mL (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Score 2</td>
<td>Score 1</td>
</tr>
<tr>
<td>Med. Anteb. Cut. sens.</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Musculocutaneous sens.</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>Musculocutaneous mot.</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Radial sens.</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Radial mot.</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Median sens.</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Median mot.</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Ulnar sens.</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Ulnar mot</td>
<td>11</td>
<td>2</td>
</tr>
</tbody>
</table>

Tabel 3  Block Scores of Individual Nerves at 30 min. Groups as defined in Table 2. Values are numbers. Med. Anteb. Cut. indicates medial antebrachial cutaneous nerve; sens., sensory block score; mot, motor block score.
reduction in dose from 600 mg to 225 mg. However, further study is required to substantiate this. The data from our study are in accordance with the studies reporting a correlation between volume of local anesthetic and duration of peripheral nerve block.

The possibility of reducing the volume (and dose) of local anesthetic with ultrasound-guided peripheral nerve block is an obvious advantage from a safety perspective. Short- to intermediate-acting local anesthetics, such as mepivacaine, are used for surgeries where postoperative pain is expected to be

### Sensory and Motor Block Duration

<table>
<thead>
<tr>
<th></th>
<th>Group 15mL (n = 13)</th>
<th>Group 40mL (n = 15)</th>
<th>Difference P</th>
<th>* %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall sensory block</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>duration</td>
<td>225 (148-265)</td>
<td>271 (210-401)</td>
<td>&lt;0.001</td>
<td>17</td>
</tr>
<tr>
<td><strong>Overall motor block</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>duration</td>
<td>217 (144-250)</td>
<td>269 (210-401)</td>
<td>&lt;0.001</td>
<td>19</td>
</tr>
<tr>
<td><strong>Med. anteb. cut. Nerve</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensory block, min</td>
<td>157 (98-235)</td>
<td>262 (191-301)</td>
<td>&lt;0.0001</td>
<td>40</td>
</tr>
<tr>
<td><strong>Musculocutaneous nerve</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensory block, min</td>
<td>154 (68-235)</td>
<td>247 (151-296)</td>
<td>&lt;0.01</td>
<td>38</td>
</tr>
<tr>
<td>Motor block, min</td>
<td>160 (114-233)</td>
<td>254 (150-311)</td>
<td>&lt;0.0001</td>
<td>37</td>
</tr>
<tr>
<td><strong>Radial nerve</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensory block, min</td>
<td>173 (103-235)</td>
<td>235 (177-401)</td>
<td>&lt;0.001</td>
<td>26</td>
</tr>
<tr>
<td>Motor block, min</td>
<td>190 (114-225)</td>
<td>262 (150-351)</td>
<td>&lt;0.001</td>
<td>27</td>
</tr>
<tr>
<td><strong>Median nerve</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensory block, min</td>
<td>184 (133-265)</td>
<td>241 (192-349)</td>
<td>&lt;0.001</td>
<td>24</td>
</tr>
<tr>
<td>Motor block, min</td>
<td>173 (129-235)</td>
<td>245 (207-301)</td>
<td>&lt;0.001</td>
<td>29</td>
</tr>
<tr>
<td><strong>Ulnar nerve</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensory block, min</td>
<td>202 (148-250)</td>
<td>252 (210-351)</td>
<td>&lt;0.001</td>
<td>20</td>
</tr>
<tr>
<td>Motor block, min</td>
<td>210 (144-250)</td>
<td>256 (210-401)</td>
<td>&lt;0.001</td>
<td>18</td>
</tr>
</tbody>
</table>

Tabel 4  Sensory and Motor Block Duration of Individual Nerves. Groups as defined in Table 2. Values are median (range). *Difference, difference between the medians of group 40 mL and group 15 mL as a percentage of the median value of group 40 mL. Med. anteb. cut. nerve indicates medial antebrachial cutaneous nerve.
Duration of overall sensory (A)

Figure 2  Dots are individual data horizontal bars represent median values.

Duration of sensory block

Figure 3  Duration of sensory block of individual nerves in group 15 mL (A) and group 40 mL (B). Dots are individual data; horizontal bars represent median values. Med. anteb. cut. indicates medial antebrachial cutaneous nerve.

moderate and/or short-lived. Block duration should cover surgery and the immediate period afterward, but prolonged analgesia postoperatively is not indispensable, and a reduction in block duration caused by reduced volume has little clinical relevance if surgery can be concluded before the block starts to wear off. Whether the pharmacodynamic findings regarding volume of mepivacaine equally apply for other local anesthetics, such as ropivacaine or
levobupivacaine, remains to be determined. In situations where a long-acting local anesthetic is preferred, a shorter duration of sensory block may be an unfavourable trade off when the intention is to obtain long-lasting postoperative analgesia. In those circumstances, the advantage of a dose reduction must be balanced against the possibility of a shorter duration of postoperative analgesia. In cases where prolonged postoperative analgesia is desirable, the use of a Perineural catheter technique should be considered. Determining the lowest volume without decreasing duration of sensory block requires further study.

A limitation of our study is that we did not determine whether intraneural spread was present; although we tried to avoid intraneural injection, we cannot exclude the possibility that this may have occurred with individual nerves, which may have prolonged block duration.

In conclusion, reducing the volume of mepivacaine 1.5% for ABPB from 40 mL to 15 mL resulted in a reduction of overall block duration of approximately 17% to 19%, a reduction of block duration in individual nerves ranging from 18% to 40%, and a reduction in TTFR of approximately 30%.

**Acknowledgments**

The authors thank Lotte Exterkate, BSc; Loes Schepers, BSc; and Anne J. W. M. de Veer, BSc, for their assistance in collecting data.

**Duration of motor block**

![Figure 4](image-url)  
**Figure 4** Duration of motor block of individual nerves in group 15 mL (A) and group 40 mL (B). Dots are individual data; horizontal bars represent median values.
References