Ultrasound Guidance Speeds Execution and Improves the Quality of Supraclavicular Block

Stephan R. Williams, MD, PhD*, Philippe Chouinard, MD, FRCPC*, Geneviève Arcand, MD*, Patrick Harris, MD, FRCSC†, Monique Ruel, RN*, Daniel Boudreault, MD, FRCPC*, and François Girard, MD, FRCPC*

From the Departments of *Anesthesiology and †Surgery, Centre Hospitalier de l’Université de Montréal, Hôpital Notre-Dame, Montréal, Quebec

In this prospective study, we assessed the quality, safety, and execution time of supraclavicular block of the brachial plexus using ultrasonic guidance and neurostimulation compared with a supraclavicular technique that used anatomical landmarks and neurostimulation. It was hypothesized that ultrasonic guidance would increase the proportion of successful blocks, decrease block execution time, and reduce the incidence of complications such as pneumothorax and neuropathy. Eighty patients were randomized into two groups of 40, Group US (supraclavicular block guided in real time by a two-dimensional ultrasonic image, with neurostimulator confirmation of correct needle position) and Group NS (supraclavicular block using the subclavian perivascular approach, also with neurostimulator confirmation). Blocks were performed using bupivacaine 0.5% and lidocaine 2% (1:1 vol) with epinephrine 1:200,000 as the anesthetic mixture. The onset of motor and sensory block for the musculocutaneous, median, radial, and ulnar nerves was evaluated over a 30 min period. At 30 min 95% of patients in Group US and 85% of patients in Group NS had a partial or complete sensory block of all nerve territories (P = 0.13 and 55% of patients in Group US and 65% of patients in Group NS had a complete block of all nerve territories (P = 0.25). Surgical anesthesia without supplementation was achieved in 85% of patients in Group US and 78% of patients in Group NS (P = 0.28). No patient in Group US and 8% of patients in Group NS required general anesthesia (P = 0.12). The quality of ulnar block was significantly inferior to the quality of block in other nerve territories in Group NS, but not in Group US; the quality of ulnar block was not significantly different between Groups NS and US. The block was performed in an average of 9.8 min in Group NS and 5.0 min in Group US (P = 0.0001). No major complication occurred in either group. We conclude that ultrasound-guided neurostimulator-confirmed supraclavicular block is more rapidly performed and provides a more complete block than supraclavicular block using anatomical landmarks and neurostimulator confirmation.

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A supravclavicular approach for blockade of the brachial plexus was first described by Kulenkampf in 1911 (1). The dissemination and use of supravclavicular blockade has been tempered by the risk of pneumothorax during localization of the nerve trunks with the injection needle and the more frequent incidence of pneumothorax when learning the technique (2,3). Interest in supravclavicular blockade has been rekindled by the use of two-dimensional ultrasonic images to localize the brachial plexus (4). The sonographic image can be used in real time to guide the injection needle while minimizing the risk of contact with structures such as the pleural dome and subclavian artery. Ultrasound-guided supravclavicular blockade has been highly successful (4), though the success rate of the technique has not been compared in a randomized study to more traditional supravclavicular approaches.

The present study was designed to compare supravclavicular blockade using ultrasonic guidance and neurostimulation to supravclavicular blockade using a surface anatomy approach and neurostimulation. It was hypothesized that ultrasonic guidance would increase the proportion of blocks allowing pain-free surgery without supplementation or the need for general anesthesia (surgical blocks), decrease execution time, and reduce the incidence of complications such as pneumothorax and neuropathy.
Methods

After IRB and written informed consent, 80 consecutive eligible patients who presented for surgery of the distal arm, forearm, or hand were randomized to two groups. Group ultrasound (US) received a supraventricular block guided by ultrasonic landmarks and neurostimulation. Group neurostimulator (NS) received a supraventricular block guided by anatomical landmarks and neurostimulation. A sample size of 40 patients per group was calculated to show a significant difference in the proportion of surgical blocks between groups, assuming 72% successful blocks in Group NS (5) and 95% successful blocks in Group US based on a review of the literature (4), accepting a probability of type 1 error of 0.05 and a probability of type 2 error of 0.2. Exclusion criteria included clinically significant coagulopathy, infection at the injection site, allergy to local anesthetics, severe pulmonary pathology, age <18 yr, no comprehension of French or English, mental incapacity precluding informed consent, a body mass index more than 35, or preexisting loss of force or sensation in the operative limb.

Light sedation (0.5–2 mg of midazolam and 25–100 µg of fentanyl) was given as needed before the block. No other sedation was administered until evaluation of the block was complete. If patients desired perioperative sedation, a propofol infusion was titrated up to 0.5 µg · kg⁻¹ · min⁻¹ to maintain constant verbal contact with the patient.

All blocks were performed with standard monitoring (pulse oximetry, noninvasive blood pressure measurement, and side-stream expired CO₂ measurement via an oxygen-delivery nasal cannula) using 25–50 mm, 22–24-gauge Teflon-coated needles (Pajunk, Geisingen, Germany; or B. Braun Bethlehem PA). The anesthetic solution consisted of equal volumes of 0.5% bupivacaine and 2% lidocaine, with 1:200000 epinephrine. This solution was administered in a single injection of 0.5 mL/kg up to a maximum of 40 mL once wrist or hand motion had been elicited with the neurostimulator delivering a current <0.6 mA. Supraventricular blocks in Group US were performed with the technique described in a recent review (6), using a 7.5-MHz ultrasonic scanning head (Aloka, Japan). Supraventricular blocks in Group NS were performed using a subclavian perivascular approach (7). All blocks were initially attempted by a senior anesthesiology resident, who performed 11 supraventricular blocks using each of the 2 research techniques while supervised by a staff anesthesiologist before beginning the project. If 20 min elapsed without adequate stimulation being obtained, a staff anesthesiologist experienced in supraventricular blockade assisted the resident.

Measured outcomes included block execution time, time of onset of sensory and motor block of the musculocutaneous, median, radial, and ulnar terminal nerves, the proportion of blocks in which surgical anesthesia was achieved, the proportion of cases in which general anesthesia was necessary, the duration of postblock analgesia as defined by the interval between block completion and ingestion of the first postoperative analgesic, and the incidence of postblock neurologic or respiratory complications. For the purposes of the study, block execution time was defined as the interval between the first needle insertion and its removal at the end of the block. Evaluation of sensory and motor block was performed every 5 min in all nerve territories over a 30-min period beginning when the stimulating needle exited the patient. Motor block was evaluated using forearm flexion-extension, thumb and second digit pinch, and thumb and fifth digit pinch, and scored as follows: no loss of force = no block; reduced force compared with the contralateral arm = partial block; incapacity to overcome gravity = complete block. Sensory block was evaluated by comparing the cold sensation elicited by ice in the central sensory region of each nerve with the same stimulus delivered to the contralateral side. Rating was quantified as normal sensation (no block), reduced sensation (partial block), or total loss of cold sensation (complete block). If any potentially surgical territory was not completely anesthetized at the time of surgery, the block was supplemented at the elbow or wrist. If the patient still experienced pain despite supplementation, general anesthesia was induced by the attending anesthesiologist using his preferred technique.

A postblock chest radiograph was obtained if a patient complained of respiratory distress. Most patients were observed in a phase II recovery area for 1–2 h after their surgery, then discharged home with oral analgesics and a detailed care sheet that included contact information. Patients were followed up by telephone one week later. The following four questions were asked:

1. “When was the first oral analgesic required?”
2. “Did any region of the arm remain insensible or weakened or generate abnormal sensations for a prolonged period of time?”
3. “Was there any respiratory difficulty encountered by the patients in the days following the block?”
4. “Does the patient have any other question or comment to report to the investigators?”

If a positive response was elicited by any of the last three questions, details were obtained.

Data are expressed as means ± one sd or proportions with 95% confidence intervals as appropriate.
Student’s t-test, Wilcoxon’s log-rank test, or Fisher’s exact test for $2 \times 2$ contingency tables were used for statistical comparisons. A $P < 0.05$ was considered significant.

**Results**

Success rates and the need for supplementation or general anesthesia are provided in Table 1. In Group US, 85% of blocks achieved surgical anesthesia without supplementation, compared with 78% in Group NS. General anesthesia was required in 0% and 8% of US and NS patients, respectively. Differences between groups were not statistically significant. Figure 1 shows the progression of the sensory block over time for each terminal nerve territory. The onset of motor blockade (not shown) paralleled that of sensory blockade. At 30 min 95% of patients in Group US and 85% of patients in Group NS had a partial or complete sensory block of all nerve territories ($P = 0.01$) and 55% of patients in Group US and 65% of patients in Group NS had a complete block of all nerve territories ($P = 0.25$). Complete anesthesia at 30 min was achieved more reliably and rapidly in the musculocutaneous and radial nerve distributions, as compared with the median and ulnar nerve distributions ($P < 0.02$ for both US and NS groups). Ulnar nerve blockade was more reliably achieved in Group US than in Group NS. At 30 min in Group NS, the proportion of patients with no ulnar block was significantly larger than for the musculocutaneous ($P = 0.01$), radial ($P = 0.01$), or median ($P = 0.05$) nerves, though not significantly larger than the proportion of patients with no ulnar block in Group US ($P = 0.13$). In Group US, the proportion of patients with no ulnar block at 30 min did not differ significantly from that observed in the other nerve territories.

There were no significant differences in the demographic characteristics of the two study groups. In Group US versus Group NS, respectively, mean age was $49 \pm 16$ versus $47 \pm 15$ yr, mean weight was $78 \pm 16$ versus $73 \pm 12$ kg, mean body mass index was $26 \pm 4$ versus $25 \pm 4$, and mean ASA physical status was II (range: I–III) versus II (range: I–III). In each group, 28% of patients received intraoperative propofol sedation to alleviate anxiety. In one patient in Group NS, a more experienced anesthesiologist performed the block after 20 min of exploration failed to elicit appropriate stimulation. Six patients had minor protocol deviations; all six were completely evaluated and their data included in the results presented below. Protocol deviations included failure to elicit wrist or hand stimulation despite extensive exploration in two patients in the NS group, both of whom were blocked successfully after anesthetic injection that abolished forearm motion elicited with a stimulating current of $<0.6$ mA.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Group US</th>
<th>Group NS</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical block</td>
<td>85 (70–94)</td>
<td>78 (62–89)</td>
<td>0.28</td>
</tr>
<tr>
<td>Supplementation</td>
<td>15 (6–30)</td>
<td>23 (11–38)</td>
<td>0.12</td>
</tr>
<tr>
<td>General anesthesia</td>
<td>0 (0–9)</td>
<td>8 (2–20)</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Data expressed as percentage of successful blocks, mean (95% confidence interval).

Group US = ultrasound-guided supraclavicular block; Group NS = neurostimulator-guided supraclavicular block; surgical block = block allowing surgery without supplementation or general anesthesia; supplementation = proportion of blocks supplemented at the elbow or wrist because of incomplete anesthesia in a surgical territory.

$P$ values given for Group NS versus Group US.

The average time necessary to perform the block was significantly shorter in Group US than in Group NS ($5.0 \pm 2.4$ min versus $9.8 \pm 7.5$ min, respectively, $P = 0.0001$; difference $= 4.8$ min, 95% confidence intervals: 2.4–7.2 min). To examine whether practice reduced the advantage of US guidance, the block execution times in the first and last 20 patients of each study group were calculated and compared within and across groups. Only Group US had significantly shorter execution times in the last 20 patients as compared with the first 20 patients ($5.8 \pm 3.4$ versus $4.2 \pm 2.2$ min respectively, $P = 0.001$). Execution times were shorter in Group US than in Group NS for both the first ($11.1 \pm 6.6$ min for Group NS, $P = 0.001$ versus US) and last ($8.6 \pm 8.2$ min for Group NS, $P = 0.01$ versus US) series of 20 patients.

The average time to acquire an ultrasonic image adequate for needle insertion (not including Doppler flow confirmation) was calculated in a subset of 10 consecutive patients and found to be $21 \pm 17$ s. This amount of time compared favorably to the time spent identifying and marking the surface anatomy ($57 \pm 14$ s) in a subset of 10 patients with similar demographics in Group NS.

One patient in each group reported respiratory discomfort after the block. In both cases, chest radiograph demonstrated an elevated hemidiaphragm compatible with ipsilateral phrenic nerve block. One patient in each group reported respiratory discomfort more than 1 wk after the block. Chest radiographs were negative in both cases and musculoskeletal pain was the final
diagnosis. No pneumothorax (95% confidence interval, 0%–9%) was diagnosed in this study.

At the 1-wk follow-up, there were no significant differences in the proportion of patients requiring postoperative analgesia (90% in Group US versus 85% in Group NS, \( P = 0.37 \)) or in the duration of postblock analgesia for those patients who required postoperative analgesia (Group US: mean 846 min, median 662 min; Group NS: mean 652 min, median 511 min; \( P = \) not significant). Persistent and new alterations in sensation were reported by five patients, three in Group US and two in Group NS. Two of these reports involved loss of sensation in the area immediately distal to the surgical incision and were attributed to surgical trauma. Three were classified as possibly related to the nerve block: one patient in the Group US who had tendon surgery of the fourth digit reported paresthesia in the ulnar nerve territory; another patient in Group US underwent tendon repair of the second digit, after which he reported hyperesthesia over a small area of the wrist; and one patient in Group NS reported a loss of sensation on the palmar surface of the thumb after the creation of an arteriovenous fistula on the forearm. All of these alterations in sensation gradually resolved over one week. No patient was lost to follow-up.

**Discussion**

This prospective randomized study demonstrates the usefulness of ultrasound guidance for the learning and execution of supraclavicular block. Ultrasound guidance allowed statistically and clinically significant reductions in procedure times and provided better block quality than a neurostimulator-guided subclavian perivascular approach.

Successful regional anesthesia depends not only on the technique used but also on proceduralist experience, block observation time, the type and amount of local anesthetic, anatomic variation, patient motivation, and the definition of a successful block. The success rate in this study was defined as anesthesia sufficient for pain-free surgery without supplementation. Success in Group US is not significantly different from the published success rate (19 of 20 based on similar criteria) in the only previous study of single-shot ultrasound-guided supraclavicular blockade (4). What difference exists is explained by a more frequent rate of supplementation for partial blocks in the present study, rather than a more frequent incidence of failed blocks. In both series, sensory block in the median and ulnar territories often completed more than 30 minutes after the block; the longer evaluation period in Kapral et al.’s study (4) showed that up to 50 minutes may be necessary to attain maximal blockade with single-shot ultrasound-guided supraclavicular block. For Group NS, the success rate as defined above was comparable to that of another series of neurostimulator-guided supraclavicular blocks using a slightly different anatomical approach, a different local anesthetic, and a different observation period (5), and block extent was similar to that described by Lanz et al. (8) using a similar technique. A successful block may also be defined as one providing complete anesthesia of all target nerves. The proportion of blocks in the present study in which all territories were completely anesthetized at 30 minutes was 55% in Group US and 65% in Group NS; the difference between these numbers and the proportion of blocks that allowed surgery is attributable to the fact that many partial blocks completed after the end of the evaluation period, as discussed above, as well as the fact that

![Figure 1. Evolution of sensory block quality and extent over the 30-min evaluation period. The onset of motor blockade (not shown) paralleled that of sensory blockade. Group US = ultrasound-guided supraclavicular block; Group NS = neurostimulator-guided supraclavicular block; MC = musculocutaneous nerve; R = radial nerve; M = median nerve; U = ulnar nerve. The relative proportions of complete, partial and no blockade for each nerve territory are expressed as percentages. \(^*\)The proportion of complete blocks at 30 min was smaller in the median and ulnar territories as compared with the musculocutaneous and radial territories \((P < 0.02\) for both US and NS groups), and partial blocks often became complete after the end of the evaluation period. \(^*\)A significantly larger proportion of patients in Group NS, but not in Group US, experienced no nerve blockade in the ulnar territory at 30 min when compared with the other nerve territories at 30 min.](image)
not all territories were subjected to surgical intervention in every surgery. These results compare favorably with the 40% success rate using similar criteria after an undefined time period described by Gaertner et al. (9) for single-shot neurostimulator-guided infraclavicular block. In contrast, Franco and Vieira (10), performing subclavian perivascular blocks (as in Group NS of this study) and using complete block of all dermatomes before surgery commenced as their criteria for success, achieved the most frequent success rates ever reported in a large series for any peripheral nerve block (973 of 1003). This series clearly shows that extensive experience with subclavian perivascular block, and perhaps a longer evaluation period, can lead to increased success rates.

Considering the limited experience of the block practitioner in this study, ultrasonic landmarks proved to be extremely reliable guides; 39 of 40 blocks in Group US took <9.8 minutes (the average time in Group NS) to perform, and nerve stimulation was often obtained on the first needle probe. Withdrawal and redirection of the stimulating needle in a search pattern frequently occurred in Group NS before appropriate neurostimulation was elicited, and in one case aid from a more experienced anesthesiologist was required. Though patient discomfort during block placement was not formally evaluated in this study, withdrawal and redirection of the stimulating needle are known to decrease patient acceptance of regional anesthesia techniques (11). Further experience with surface anatomy-based technique could reduce or perhaps even eliminate the advantage of ultrasound guidance. However the inherent variability in the relationship between surface anatomy and nerve location will occasionally frustrate even the most experienced proceduralist, whereas ultrasonic localization appears to minimize this source of variation in procedure times.

The possibility of creating a pneumothorax is a concern when attempting supraclavicular block. The published incidence of pneumothorax varies between 1% and 4% using the classical supraclavicular approach and paresthesia for nerve localization (12–14). Several alternative supraclavicular approaches have been described in an attempt to minimize the incidence of pneumothorax (5,7,15,16); at least one of these (the subclavian perivascular approach) has been shown in a large series to have an incidence of clinically significant pneumothorax less than the classical approach (10). To minimize patient risk in this study, the subclavian perivascular approach was used in Group NS. Ultrasonic guidance is also thought to decrease the incidence of pneumothorax during supraclavicular blockade (4); no pneumothorax has been reported during ultrasound-guided supraclavicular block. No clinically significant pneumothorax occurred in either study group. Systematic postblock radiographs were not obtained; therefore, asymptomatic pneumothoraces may have occurred. Elevated hemidiaphragms observed in both postblock radiographs taken in this study probably represented phrenic nerve block, which occurs in 40%–60% (3) of supraclavicular blocks.

Experience with supraclavicular blockade is thought to reduce the incidence of complications (14); however, the amount of practice necessary to master supraclavicular blockade remains an open question. A study examining the number of brachial plexus blocks needed to attain a reasonable degree of proficiency with the technique estimated that at least 62 blocks should be performed to achieve a success rate of 87% (17). However, a recent survey of US anesthesia residents showed that the 50th percentile for exposure to nerve blocks of any kind during an entire residency consisted of 45 procedures (18). This number of blocks may not allow most residents to complete their nerve block learning curve before entering practice. Ultrasonic guidance, by specifying for each patient the location of the target nerves, their relation to neighboring structures, and the path of the needle by which local anesthetic will be injected (19), could allow trainees to become more safe and successful in nerve blockade within the limited exposure provided by a typical residency program.

The use of newer imaging techniques has been described as “critically important to the future” of regional anesthesia (20); the future of ultrasound-guided blocks will depend in part on whether or not the clinical benefits associated with imaging technology justify equipment acquisition costs. The present study shows that the theoretical advantages of ultrasound localization translate into clinically useful benefits. We conclude that ultrasound-guided neurostimulator-confirmed supraclavicular block is more rapidly performed and provides a more complete block than supraclavicular block using only anatomic landmarks and neurostimulator confirmation.

References