High-Resolution Ultrasound Imaging Guidance Increases Efficacy And Safety of Supraclavicular Brachial Plexus Block

Moataz Morad El-Tawil, Mohamed Yasser Elbahar
Anesthesia Department, Faculty of Medicine, Menoufya University

ABSTRACT
High frequency ultrasound (12 MHZ) imaging equipped with a digital linear scanhead offers excellent resolution of superficial structures during brachial plexus block. Ultrasound can be used to identify the brachial plexus before block, guide the block needle to reach the target nerves, and visualize the pattern of local anesthetic spread. In the present study we compared the state-of-the-art ultrasound technology for supraclavicular brachial plexus block with the classical technique that depended on the anatomical landmarks as regard efficacy, quality and safety. We found that ultrasonic guidance decreased the time to perform the block, shortened the onset of block, prolonged the duration of postoperative analgesia, increased the proportion of successful blocks, increased patient's satisfaction and reduced the incidence of complications than the classical method of supraclavicular blocks.

Conclusion: High resolution ultrasound guided supraclavicular block is easier, more effective, of better quality, and safer than the classical block that depends on the anatomical landmarks.

INTRODUCTION
Peripheral neural blockade is now a well-accepted component of comprehensive anesthetic care. Its role has expanded from the operating suite into the arena of postoperative and chronic pain management. With appropriate selection and sedation, these techniques can be used in all age groups. Skillful application of peripheral neural blockade broadens the anesthesiologist's range of options in providing optimal anesthetic care.

The supraclavicular approach to the brachial plexus is anesthetically efficient; a small volume of solution can be delivered at a point in which the three trunks are compactly arranged, resulting in rapid onset of reliable blockage of the brachial plexus. The block can also be performed with the patient's arm in any position, to provide excellent anesthesia for elbow, forearm, and hand surgery.

The key steps in any successful regional anesthetic technique involve identifying the exact position of the nerve, reaching it with a precisely placed needle (without damage to any adjacent structures), and finally, carefully injecting right dose of the right drug.

The success of the classical supraclavicular approach to the brachial plexus block depends on a good understanding of anatomy and strong reliance on landmarks which may be obscured by obesity or anatomical variation. Because of the blind nature of this technique unpredictable block failure, inadvertent puncture of adjacent structures (blood vessels, pleura and nerves) may occur leading to complications or, frustrating and time-consuming trial, and error attempts.

The introduction of the peripheral nerve stimulator into clinical practice was a major advance. Unfortunately, even with this tool, performance is still far from perfect again because of the blind nature of this technique.

Ultrasound-facilitated nerve blocks were first reported in 1978, and interest has increased in the past 10 years owing to progress in transducer technology, image processing, portability and cheaper equipments.

High frequency ultrasound (12 MHZ) imaging equipped with a digital linear scanhead offers excellent resolution of superficial structures during brachial plexus block.

Ultrasound can be used to identify the brachial plexus before the block, guide the block needle to reach the target nerves, and visualize the pattern of local anesthetic spread.

It was hypothesized that ultrasonic guidance would decrease the time to perform
the block, speed the onset of the block, prolong the duration of postoperative analgesia, increase the proportion of successful blocks, improve the quality of the blocks, and reduce the incidence of complications, relative to the classical technique of supraclavicular brachial plexus block (5).

The purpose of this study was to compare the state-of-the-art ultrasound technology for supraclavicular brachial plexus block with the classical technique that depend on the anatomical land-marks as regard the efficacy, quality and safety.

METHODS

The study received approval from the Institutional Medical Research Ethics Committee. Eighty patients, ASA 1-2, aged >18 yr., presenting for upper limb surgery were randomly allocated into one of two equal groups, a classical (C) group where the supraclavicular brachial plexus block was guided by the anatomical landmarks and ultrasound (US) group where the same block was guided by ultrasound real time imaging. Exclusion criteria included patients refusing local anesthetic technique, patients with dementia, peripheral neuropathy, sensitivity to amide local anesthetics, severe renal, hepatic, respiratory or cardiac disease, and women who were pregnant or lactating.

All patients were visited before surgery and were given a full explanation; written informed consent was obtained. On patient's arrival in the anesthetic room, a 20 G intravenous cannula was inserted in the hand not being operated upon and full non-invasive monitoring commenced (NIBP, ECG, SPO2). Small doses of midazolam (0.2 mg/kg) and fentanyl (0.5 µg/kg) were administered and oxygen 2 liters min-1 was delivered through a nasal canula. In the classical (C) group, the patient was positioned supine with the head turned about 30 degree to the contralateral side. The subclavian pulse can be felt in a plane just medial to the midpoint of the clavicle. After a skin wheal, with lidocaine a 22 gauge, 1.5 inch blunt-bevel needle is directed just above and posterior to the subclavian pulse and directed caudally at a very flat angle against the skin, the needle was connected to sterile extension tubing attached to a stopcock and 20-ml syringe, and flushed with the local anesthetic until air in the system was completely removed. The needle is advanced until paresthesia is encountered where a 0.5 ml/kg of a local anesthetic solution formed of lidocaine 2% and bupivacaine 0.5% (1:1 vol.) with epinephrine (1:200 000) and sodium bicarbonate (0.9 mEq/10 ml), was injected in small divided doses after frequent negative aspiration for blood. If the rib is encountered without paresthesia or if blood is encountered, the needle is withdrawn and the landmarks as well as the plane of the needle are reevaluated. In the ultrasound (US) group, while the patient is in the same previous position, a high frequency lineal array ultrasound probe (L12-5 MHZ) Mobile Ultrasound apparatus (Kontorn Medical, Sigma 5000 series, IMAGIC EN, 5-12 LA, version 1.32, France 2004) was moved lateral to the sternocleidomastoid muscle toward the supraclavicular region in a coronal-oblique plane (Fig. 1) to visualize a transverse view of the supraclavicular brachial plexus which lies cranialateral to the pulsating subclavian artery and between the anterior scalene (medially) and median scalene (laterally) muscles and superficial to the cervical pleura and first rib. The nerves of the brachial plexus (trunks) appear as a multiple rounded or oval hypoechoic areas encircled by a relatively hyperechoic horizon (Fig. 2). After skin preparation with betadine solution and after application of a sterile probe cover, and sterile gel and under direct real-time ultrasound imaging guidance, an 18-gauge Tuohy needle without a stylet connected to a sterile extension stopcock and 20 ml syringe was inserted (after a skin wheal) and advanced until it was seen in contact of the target nerves. To optimize visualization of the needle shaft and tip, the needle was inserted at the skin on the outer end of the ultrasound probe (cranialateral to the probe) so that the path of needle advancement would be in-line with and in the same plane as the ultrasound beam (Fig. 3). Once the needle was judged in satisfactory position (in contact with the brachial plexus in the supraclavicular location, (Fig. 4), the local anesthetic was injected under direct visualization and its distribution was confirmed when encircling the target nerves. The injection was over 1 min, with repeated aspirations every 5 ml.
In both groups, after injection of the local anesthetic, assessment of the resulting block and hemodynamic variables was recorded as described below. After 30 min, if the block was considered to be adequate, surgery commenced. The patient was sedated, if requested, using infusion of propofol. If the block was considered to be inadequate for surgery, the patient was given general anesthesia.

All blocks in both groups were carried out by one anesthesiologist experienced in the technique of supraclavicular brachial plexus block and trained on the ultrasonography of the supraclavicular region with help of on duty radiologist. The time to perform the block was recorded starting from skin preparation till complete local anesthetic injection.

All the following assessments were done by one blinded assistant at 5, 10, 15, 20, 25 and 30 min with time 0 min. being the time of completion of local anesthetic injection. Sensory block was initially tested by pinching the skin of the hand, forearm, and arm at dermatomes from C5 to T1 when a decreased response to pinch was noted, a 22-gauge needle was used to evaluate the sensory block in tested area. The onset of sensory block was defined as the time to diminished response to pinch in all dermatomes, while the time to complete sensory loss was the time to loss of pinprick sensation in all dermatomes. Motor block was evaluated by asking the patient to move the shoulder, elbow, and/or wrist. The onset of motor block was defined as the time to motor weakness of the three joints, while the time to complete motor block was the time to complete motor paralysis of the shoulder, elbow, and/or wrist. At 30 min an overall assessment of the quality of the block was made on a three-point scale: 0 = complete failure; 1 = unsatisfactory block (inadequate analgesia, inadequate relaxation or patient required general anesthesia because of agitation or restlessness) and 2 = satisfactory block. For statistical analysis, complete failure and unsatisfactory blocks were considered together as failure and compared with the success (satisfactory block).

The duration of postoperative analgesia was defined as the time from the end of the operation till the patient's first request of analgesia.

The incidence of complications was noted and recorded in both groups like (failure of the block, inadvertent puncture of blood vessels, pneumothorax, Horner's syndrome, phrenic nerve block, and postoperative neuropathies), in the first 24 hours.

Patient satisfaction with the techniques in both groups was assessed using, Visual analog score of 0-10 (0= not satisfied, 10= entirely satisfied) after 24 hours postoperatively.

**Statistical analysis**

Results are expressed as mean ± SD unless otherwise stated. Demographic data were assessed using the Mann-Whitney test. The time performing the block, onset of sensory and motor blocks, duration of surgeries, first demand of analgesia by the patient were compared with Mann-Whitney test, and side effects were analyzed using the Fisher exact test. For all determinations, a F value <0.05 was considered significant.

**RESULTS**

The two groups were similar with regard to demographic and surgical data (Table I).

There were no significant differences between the two groups as regard the NIBP, HR and SPO2 and their values were clinically accepted throughout the procedures.

The time to perform the block was significantly shorter in US group than C group (5.8 ± 2.4 Vs 10.2 ± 4.1 min respectively) (F<0.05) (Table II).

The onset of sensory block in US group was significantly shorter than C group (9.2 ± 4.1 Vs 15.7 ± 5.1 min respectively) (F<0.05) (Table II).

The time of complete sensory loss in US group was significantly shorter than C group (18.4 ±5.3 Vs 25.1 ± 7.2) (Table II).

The onset of motor block in US group was significantly shorter than C group (11.9 ±6.2 Vs 16.3 ± 4.6 min respectively) (F<0.05) (Table II).

The time to complete motor paralysis in US group was significantly shorter than C group (19.8 ± 5.7 Vs 26.5 ±7.8) min respectively) (F<0.05) (Table II).

At 30 min after injection of local anesthetic solution, in group US there was 2 (5%) failure of the block, while in group C there was 8 (20%) failures of the block, these
cases of failure received general anesthesia to start the surgical procedures (Table II). The score of block quality after 30 min from injection was significantly better in US group than C group (1.93 ± 7.2 vs 1.7 ± 2.3 respectively) (F<0.05) (Table II).

The duration of postoperative analgesia was significantly longer in US group than C group where the time of first request of analgesia was (907 ± 323 Vs 610 ± 202 minutes respectively) (F<0.05) (Table II).

The patient’s satisfaction score was higher significantly in US group than in C group (9.1 ± 2.7 Vs 6.2 ± 1.7 respectively) (F<0.05).

The total incidence of complications was significantly lower in US group compared to C group (17.1% to 5.4% respectively) (F<0.05).

The incidence of each complication is illustrated in Table (II).

Fig. 1. Ultrasound probe position at five anatomical locations. It is directed in the axial oblique plane for the interscalene location (1), coronal oblique for the supraclavicular location (2), parasagittal for the infraclavicular location (3), transverse for the axillary location (4), and transverse for the midhumeral location (5).
**Fig. 2.** Transverse sonogram in the supraclavicular region shows brachial plexus as a group of hypoechoic nodules (N with arrows) lateral to subclavian artery (SA) and cephalad to the first rib (R). PL= pleura, SAM= scalenus anterior muscle, SV= subclavian vein.

**Fig. 3.** The ultrasound guided needle advancement technique, showing one hand holding the probe and the other hand holding the Touhy needle in the supraclavicular location. The needle is positioned at the lateral end of the ultrasound probe and passed in-line with the ultrasound beam i.e. in the same plane.

**Fig. 4.** Sonogram of the needle (arrows) in contact with the brachial plexus in the supraclavicular location. SA= subclavian artery.

**Table I: Demographic data and duration of surgery in the two groups**

(values are mean ± S.D.)

<table>
<thead>
<tr>
<th></th>
<th>Group C N= 40</th>
<th>Group US n= 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender M/F</td>
<td>28/12</td>
<td>27/13</td>
</tr>
<tr>
<td>Age (years)</td>
<td>42 ± 15</td>
<td>46 ± 17</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>72 ± 12</td>
<td>74 ± 11</td>
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</table>
Table II: Characteristics of the supraclavicular block and the incidence of complications

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group C n= 40</th>
<th>Group US n= 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to perform the block (min)(^a)</td>
<td>10.2 ± 4.1</td>
<td>5.8 ± 2.4*</td>
</tr>
<tr>
<td>Onset of sensory block (min)(^a)</td>
<td>15.7 ± 5.1 (n=32)</td>
<td>9.2 ± 4.1* (n=38)</td>
</tr>
<tr>
<td>Onset of motor block (min)(^a)</td>
<td>16.3 ± 4.6 (n=32)</td>
<td>11.9 ± 6.2* (n=38)</td>
</tr>
<tr>
<td>Time to complete sensory block (min)(^a)</td>
<td>25.1 ±7.2 (n=32)</td>
<td>18.4 ±5.3 (n=38)</td>
</tr>
<tr>
<td>Time to complete motor block (min)(^a)</td>
<td>26.5 ±7.8 (n=32)</td>
<td>19.8 ±5.7* (n=38)</td>
</tr>
<tr>
<td>Block quality score</td>
<td>1.7 ± 2.3 (n=32)</td>
<td>1.93 ± 7.2* (n=38)</td>
</tr>
<tr>
<td>Duration of analgesia (min)(^a)</td>
<td>610 ± 202 (n=32)</td>
<td>907 ± 323 (n=38)</td>
</tr>
<tr>
<td>Patient's satisfaction score</td>
<td>6.2 ± 1.7 (n=32)</td>
<td>9.1 ± 2.7* (n=38)</td>
</tr>
<tr>
<td>Failure of block(^b) n (%)</td>
<td>8 (20%)</td>
<td>2 (5%)*</td>
</tr>
<tr>
<td>Pneumothorax n (%)</td>
<td>1 (2.5%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Vascular puncture n (%)</td>
<td>5 (12.5%)</td>
<td>0 (0%)*</td>
</tr>
<tr>
<td>Postoperative neuropathy n (%)</td>
<td>4 (10%)</td>
<td>1 (2.5%)*</td>
</tr>
<tr>
<td>Phrenic nerve paresis n (%)</td>
<td>13 (32.5%)</td>
<td>6 (15%)*</td>
</tr>
<tr>
<td>Horner's syndrome n (%)</td>
<td>10 (25%)</td>
<td>4 (10%)*</td>
</tr>
<tr>
<td>Total incidence of complications (%)</td>
<td>17.1%</td>
<td>5.4%*</td>
</tr>
</tbody>
</table>

\(^a\)Mean ± SD  
\(^b\)Patients received general anesthesia  
*F<0.05

**DISCUSSION**

Regional anaesthesia always works—provided you put the right dose of the right drug in the right place. When it does not work, it is usually because the local anesthetic has not been put in the right place\(^b\).

Our preliminary data suggest that it is technically feasible to localize accurately and consistently the brachial plexus at the supraclavicular region and identify the adjacent vital structures, using high-resolution ultrasound imaging. The ability to visualize depends on the depth of penetration of the ultrasound beam. With the lineal L12-L5 MHz probe, we obtain excellent images of the brachial plexus as it is situated superficially (within 1-2 cm from the skin surface) at this location\(^b\).

Our study has demonstrated that high-frequency ultrasound probing up to 12 MHz can quickly generate clear images of the supraclavicular part of the brachial plexus, visually guide the needle to reach target nerves with precision, show nerve movement when the needle makes contact with the nerve, and examine the pattern of local anesthetic spread around the nerves, while identifying the adjacent structures to avoid their accidental puncture. Thus, ultrasound is like a dispassionate eye above the needle to control what we are doing and to give nerve blocks an objective basis.

The use of ultrasound technology for regional anesthesia has been reported in earlier studies for example, in 1978, La Grange and colleagues\(^10\) reported the use of a Doppler ultrasound device to aid identification of the subclavian artery and vein before brachial plexus block by the supraclavicular approach in 61 patients. Their success rate was 96% and there were no complications. Older technology of ultrasonography, probes <7 MHz, identifies vascular and bony structures but not nerves. Thus earlier attempts of ultrasound-assisted brachial plexus block rely on identification of the subclavian or axillary artery, the principal
landmark for needle placement. For example, Ootaki et al.\(^{11}\) performed infraclavicular brachial plexus block guided by a 7-MHz probe. Needle and local anesthetic were placed adjacent to the subclavian artery without visualization of the brachial plexus nerves. Local anesthetic injection generates a ring-shaped shadow around the artery and results in consistent success. With advanced ultrasound technology today, it is now possible to visualize the nerves of the brachial plexus using high-frequency probes. So the technology and clinical understanding of anatomical sonography should have a role in the future training of anesthetists.

In the present study, we compared state-of-the-art ultrasound technology (high-resolution ultrasound system, provided with software that allowed optimal visualization of tissue contrast and colour flow imaging that allowed identification of vessels) to facilitate supraclavicular brachial plexus block, with the classical technique. We demonstrated that ultrasound guidance significantly shortened the time to perform the block and the onset of sensory and motor nerve blocks, prolonged the duration of postoperative analgesia, increased the proportion of successful blocks, increased satisfaction of the patients and reduced the incidence of complications. So, we believe that ultrasonography should be used more routinely particularly in the more difficult supraclavicular blocks in cases such as the obese and those with coagulopathy and respiratory diseases, because it quickly and easily defines the target nerves we wish to block and also vital structures (pleura and vessels) we wish to avoid. Manfred and Stephan\(^{14}\) stated that ultrasound has proved helpful for regional anesthesia in two ways: First, it allows the systemic, non invasive, in vivo assessment of topographic sonoanatomy and its variations. Second, ultrasound helps to individually guide the needle in real-time, and that ultrasound guidance offer the anesthetist a unique chance to improve block success and a decrease in the rate of complications, even if he is less experienced in regional techniques. Devices have become user-friendly, more portable, more affordable, more available, cheaper, and can produce better quality imaging, and can be shared with other specialties\(^{12}\). Ultrasound guidance can make regional anesthesia more of a science rather than an art. Consequently, after achieving today’s high transmitter frequencies, our next step should be to markedly increase application frequency.

Sandhu and Capan\(^{13}\) found that the use of ultrasound guided brachial plexus block, appears to permit accurate deposition of the local anesthetic perineurally and to be associated with a high success rate, short onset time, easy placement of catheter, low complication rate, and excellent analgesia and that the conventional techniques for brachial plexus blocks using anatomic landmarks or even nerve-stimulation guidance are blind in nature and can result in unpredictable block failure, inadvertent puncture of adjacent structures leading to complications, or frustrating and time-consuming trial, and error attempts.

Peterson et al.\(^{12}\) stated that the anesthetists should use ultrasound to guide needle insertion in nerve blockade especially in certain blocks for which the complications rate is high or serious such as brachial plexus blocks.

Because of the lose proximity of the brachial plexus to the cervical pleura, and the reported incidence of pneumothorax (0.5-6%) with the classical supraclavicular brachial plexus block technique,\(^{1}\) Harmon and Frizell\(^{15}\), had contraindicated this approach in day-case surgery especially because the pneumothorax is usually small and slow developing up to 24 hs. However, Marhofer et al.\(^{7}\) stated that it is inappropriate to regard the supraclavicular approach as a routine procedure, no matter how much it is facilitated by ultrasound guidance.

Marhofer et al.\(^{7}\) stated that ultrasound visualization of anatomical structures is the only method offering safe blocks of superior quality of optimal needle positioning. In addition the amount of local anesthetic needed for effective nerve block can be minimized by directly monitoring its distribution. They also demonstrated that ultrasound guidance significantly improved the puncture-to-onset interval and the quality of sensory and motor block while avoiding complications, because local anesthetics could be applied more accurately with ultrasound guidance compared with the blind classical technique.

Vienna study group developed an ultrasound-guided technique for the supraclavicular approach and compared it with the
axillary approach, demonstrating that a high success rate could be obtained even with ultrasound equipment that was state-of-the-art in 1994(16).

More recently, William et al.(17), compared the same technique with nerve stimulation guidance and found that ultrasound guidance was superior, which is in accordance with other studies of upper and lower extremity blocks. They concluded that, while inexperienced users may prefer to use both nerve stimulation and ultrasound to verify the position of the needle, it is generally better to avoid nerve stimulation, thereby sparing the patient the painful muscle contractions associated with this approach.

CONCLUSION

We concluded that, state-of-the-art ultrasound technology can provide high-quality images of the supraclavicular part of the brachial plexus and its surrounding vital structures, and aid nerve localization by guiding needle penetration moment-by-moment to the target nerves. So, ultrasound guided supraclavicular block technique is superior to the classical technique by improving, the puncture-to-onset interval, the onset of sensory and motor blocks, postoperative analgesia, patient's satisfaction, while avoiding complications.

REFERENCES