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Ultrasound-guided Brachial Plexus Anesthesia

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Interest in regional anesthesia has waxed and waned since its introduction into clinical practice over a century ago. The elegance, safety,[1] and comfort[2,3] of a successful peripheral nerve block are undeniable. However, high success rates using these techniques are dependant on regular practice and intrinsic operator ability and even the most experienced and skilled operator occasionally encounters difficulty in successfully locating a target nerve. The use of imaging modalities to speed performance and improve the success rate of regional anesthesia is currently under investigation.[4-6] At the moment, ultrasonic guidance (USG) appears to offer the best compromise between cost, portability, accessibility, and imaging quality. The aim of this issue of *Anesthesiology Rounds* is to provide a concise summary of the current state of the art of USG nerve blocks. The focus of this issue will be on peripheral nerve blocks of the upper limb.

TO NEUROSTIMULATE OR NOT TO NEUROSTIMULATE

Neurostimulation is the current gold standard for nerve localization. The equipment necessary for neurostimulation is compact and relatively inexpensive. In skilled hands, it has been repeatedly demonstrated that high success rates are achievable when performing peripheral blocks guided by surface anatomy and neurostimulation.[7,8] The disadvantages of neurostimulation include patient discomfort requiring sedation to improve patient acceptance,[8,9] lack of evoked response even when the needle to nerve distance is minimized,[10] and an inability to prevent complications due to penetration of adjacent vascular or other structures by the stimulating needle.

When USG is compared to neurostimulation, 3 advantages are immediately apparent.[11] These include the ability to visualize:

- both the target structure and adjacent complication-producing structures
- the path of the block needle, allowing the best path to the target structure to be selected.
- the injection of local anesthetic in real time, allowing corrections to be made if the pattern of deposition appears inadequate.

Can neurostimulation be used in conjunction with USG to further improve block quality? Many authors consider neurostimulation and USG as complementary[12,13] and, certainly, when learning a USG technique, neurostimulatory confirmation is reassuring. However, as one progresses with USG blocks confirmed by neurostimulation, problems with the neurostimulatory endpoint for injection are observed. It may be impossible to evoke a motor response even though the stimulating needle is directly adjacent to the nerve,[10,14] a frustrating experience that

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highlights an important shortcoming of neurostimulation. Perhaps even more important, inappropriate distribution of the local anesthetic is occasionally observed even after an appropriate motor response has been obtained using neurostimulation. In fact, a study recently performed in our hospital demonstrated that for USG infraclavicular blocks, the addition of neurostimulation actually *decreased* the proportion of complete blocks, while *increasing* execution times.[15]

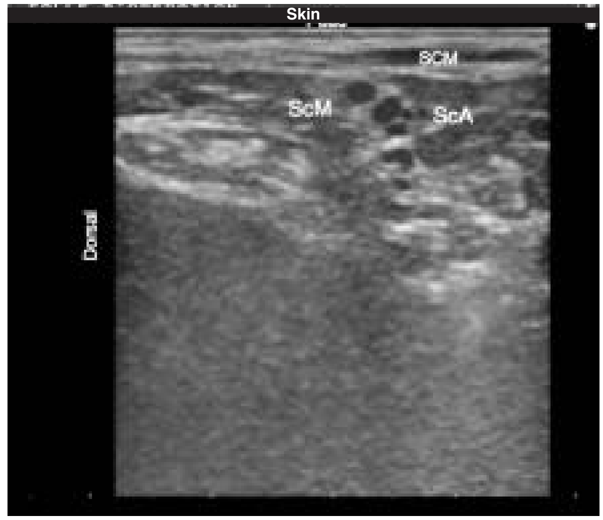
TECHNICAL ASPECTS

A thorough discussion of the physics and technical intricacies of ultrasound imaging is beyond the scope of this review. However, certain basic technical aspects that strongly influence image quality are worth highlighting.

Probe frequency is a critical determinant of the spatial resolution of the ultrasound image, with lower frequency probes producing lower resolution images, all else being equal. Higher frequency probes can produce stunningly detailed images of superficial structures, including the brachial plexus at the interscalene, supraclavicular, axillary, and mid-humeral levels.[10] However, higher spatial resolution is achieved at the expense of lower penetration, making deeper structures such as the brachial plexus at the infraclavicular level more difficult to visualize with a high frequency[10] than with a low- or mid-frequency probe.[16,17] Linear probes are generally preferred for USG brachial plexus blocks, although curved probes have also been used with success.[18] Colour flow imaging can be useful to differentiate vascular from other structures. Sophisticated electronic processing of the ultrasonic signal further increases image quality in mid- to high-end ultrasound systems.

Needle visualization is only possible when ultrasound is reflected from the needle back to the probe. Keeping the entire needle under the probe allows visualization of the whole shaft, whereas, when the needle is only partially under the probe, very little of the shaft may be visualized. Partial visualization of the needle can be dangerous if the point at which the needle leaves the imaging plane is incorrectly interpreted as the needle tip, since the actual needle tip can then unknowingly be advanced into deeper structures. For beginning ultrasonographers, the *most* frequent error is continuing to advance a needle that is only partially visualized.[19] The importance of knowing where the needle tip is in the patient cannot be stressed enough, as this information is the key to decreasing

FIGURE 1: Interscalene echoanatomy. The roots of the brachial plexus appear as hypoechogenic rounded structures sandwiched between the anterior and middle scalene muscles (ScA and ScM, respectively).



complications through USG. Needle size, as well as the angle of introduction, also play an important role in determining the amount of ultrasound reflected back to the probe, with larger needles and shallower angles of introduction allowing better visualization.[20] Although direct visualization of the entire shaft is ideal, needle position is often partially inferred from the movement of adjacent tissues.

For a detailed discussion of ultrasonic anatomy of the brachial plexus, readers are referred to De Andres et al,[21] who provides an excellent correlation between actual cadaveric cross-sections and corresponding ultrasound images. When viewed with ultrasound, nerves can be hyper- or hypoechoic, depending on the level and angle at which they are viewed, the density of surrounding structures, and individual variations. Basic information regarding the echographic appearance of nervous structures is given in the discussion below.

UPPER LIMB TECHNIQUES

Interscalene block

At the interscalene level, the brachial plexus roots often appear as hypoechoic nodules arranged like peas in a pod between the anterior and middle scalene muscles (Figure 1, all figures have been enhanced for illustrative purposes). The lack of a vascular landmark sometimes makes localization of the nervous structures more difficult, especially when learning the technique. It may be useful to visualize the brachial plexus at

FIGURE 2: Supraclavicular echoanatomy. The trunks of the brachial plexus (T) appear as heterogenous structures posterocephalad to the supraclavicular artery (Art).

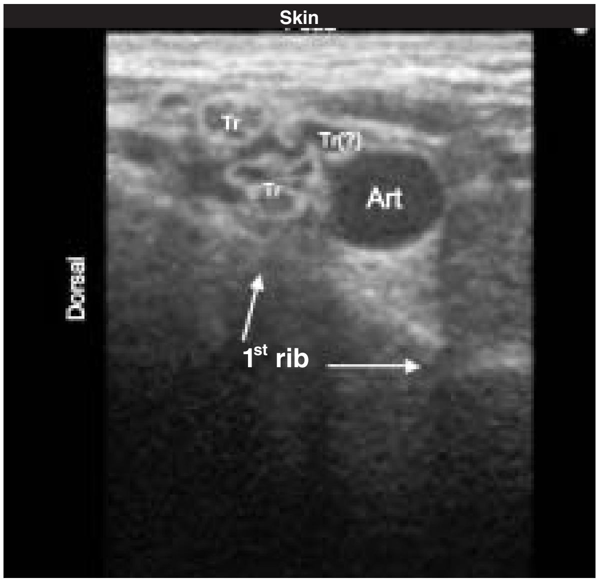
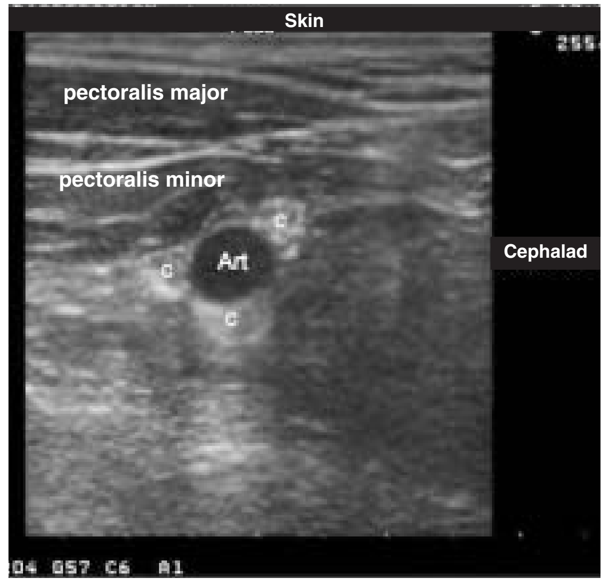


FIGURE 3: Infraclavicular echoanatomy. The cords of the brachial plexus (C) appear as hyperechogenic structures posterior and to each side of the axillary artery (Art).



the supraclavicular level, then follow the nerves back up into the interscalene groove. Successful USG interscalene blocks, with[13] or without neurostimulatory confirmation of correct needle position, have been described. Visualization of the nerve roots bathed in local anesthetic in an interscalene groove distended by the injected solution reliably predicts success. The advantages of USG over neurostimulation alone have not yet been demonstrated. However, the rare, but disastrous pulmonary and neurological complications associated with brachial plexus block at this level,[22,23] make ultrasonography an attractive guidance modality.

Supraclavicular block

At the supraclavicular level, the brachial plexus usually appears as a bundle of hypoechoic nerve structures encased in a hyperechoic sheath (Figure 2). This bundle is situated cephalodorsally to the supraclavicular artery, which provides a fairly reliable vascular landmark to guide needle positioning if direct visualization of the nerve structures proves to be difficult. USG supraclavicular block has been well-studied by our group at the University of Montreal, as well as by others.[10,12,17,24,25] With an operator who is equally experienced in both techniques, USG supraclavicular block was shown to be superior to neurostimulator-guided supraclavicular block, providing better block quality with shorter execution times, even though neurostimulation was used as the endpoint for injection in both groups.[25] More experienced operators report extremely high success rates with excellent block quality using this approach.[12] Visualization difficulties sometimes occur in patients with very wide necks. Adjacent structures such as the lung are clearly visualized and, therefore, easy to avoid as long as the location of the needle tip is known. To date, no case of pneumothorax has been reported during USG supraclavicular block, though it is conceivable that, if visualization of the needle tip is lost during the procedure and the needle is subsequently advanced unreasonably far, the lung could still be punctured.

Infraclavicular block

The infraclavicular approach has several advantages when combined with ultrasonography. At this level, the brachial plexus is usually divided into 3 cords compactly arranged medially, laterally, and inferiorly to the axillary artery. These cords are generally reported as hyperechoic or mixed nodular structures when viewed using ultrasonography (Figure 3). USG obviates the need to use unreliable surface landmarks[4,26] when performing this block. Using USG, an infraclavicular block is quickly and reliably performed with a minimum of patient discomfort.[15,17] Several

FIGURE 4: Five o'clock infraclavicular block. The needle is placed (as shown) immediately adjacent to the axillary artery, the objective being to deposit local anesthetic (C) in a "U" around the artery.

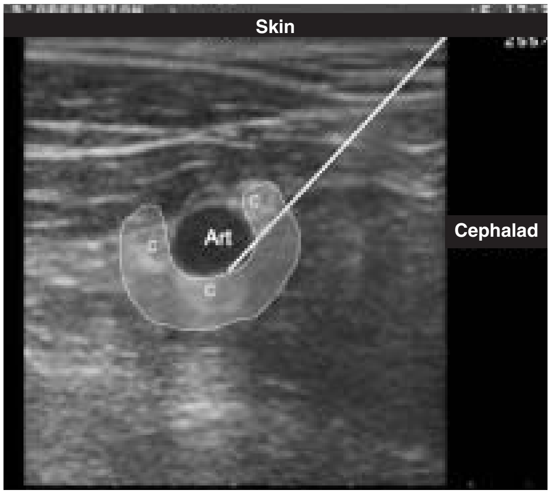


FIGURE 5: Axillary echoanatomy. Individual nerves (Median: M; Ulnar: U; Radial: R; Musculocutaneous: MC) can often be visualized around the artery (Art).

series have demonstrated that highly successful blocks are possible when the axillary artery is surrounded by local anesthetic deposited either circumferentially[27] or as a posterolateral "U."[15,16] Our group has shown that neurostimulatory confirmation before local anesthetic injection *decreases* the success rate of infraclavicular block.[15] This lower success rate is related to inappropriate local anesthetic deposition despite adequate neurostimulation having been achieved.[15] If the most ventral portion of the axillary artery is defined as "12 o'clock," we have found that by placing the needle at 5 or 7 o'clock immediately adjacent to the artery, adequate spread of local anesthetic is almost always achieved with a single injection point (Figure 4). This "5 O'clock Block" is the first technique taught to beginning ultrasonographers at our institution. Potential pitfalls for USG infraclavicular block include technical difficulty visualizing the brachial plexus at this depth using high frequency probes,[10] and anatomical variations in which the axillary vein interferes with needle positioning.

Axillary block

At the axillary level, using high frequency probes, the brachial plexus appears as discrete nerves. Usually, these have the appearance of hyperechoic bundles containing several small hypoechoic nodules that are suggestive of fascicles (Figure 5). When examined using ultrasound, a surprising amount of anatomical variation is seen in the relative positions of the vascular and nervous structures.[10] Little has been reported on USG axillary block techniques.[12] Our experience at the University of Montreal using medium to high frequency probes suggests that the superficial localization of the nervous structures allows shallow needle approaches that produce excellent visualization of the entire needle shaft and tip, thus allowing rapid and precise deposition of local anesthetic on either side of the artery (vascular landmark technique) or directly next to individually identified nerves. Success rates with these techniques appear promising.

Individual nerve blocks

An interesting report by Gray and Schafhalter-Zoppoth[28] demonstrates how ultrasound technology has the potential to transform the practice of regional anesthesia. Using a high-frequency probe, the ulnar nerve was followed along its course through the forearm and injection was performed at the mid-forearm level where no surface or vascular landmarks are available for localization. Successful block was achieved in 2 patients in whom the technique was attempted. The implication of this report is that direct identification of a nerve using ultrasound allows successful nerve blockade, even at levels where anatomical landmarks are unreliable or unavailable.

DISCUSSION

Though still in its infancy, USG regional anesthesia has already demonstrated advantages over neurostimulation, whether it be in terms of block execution times[25] or block quality.[15,25] In the hands of some operators, neurostimultion allows excellent results once a given technique has been mastered. However, the learning curves for neurostimulatory-guided blocks are long: one study estimated that >60 brachial plexus blocks need to be performed to achieve a loosely defined success rate of 87%.[29] This number of blocks may not allow anesthesia residents to complete their nerve block learning curves before entering practice. Also, practicing anesthesiologists who perform neurostimulator-guided brachial plexus blocks only occasionally, often feel they have to focus on a single approach in order to develop and maintain an acceptable level of clinical success. In contrast, USG allows relatively inexperienced practitioners to achieve high success rates after only a few blocks.[15,17,25] The rapid learning curve, high level of feedback, low level of patient discomfort, and good success rates with USG-guided blocks make these techniques attractive, even to anesthesiologists who may not have been interested in regional anesthesia in the past.

While USG can improve success rates and shorten procedure times, it is not a regional anesthesia panacea. The cornerstones of successful neural blockade will always remain appropriate selection and correct dosage of local anesthetic, incremental injections, allowing sufficient time for block onset, evaluation of block quality before commencing surgery, and appropriate patient selection and sedation. Also, although the learning curve is short, proficiency with USG blocks is not instantaneous. Novice anesthesiologists wishing to use USG must give themselves, their hands, and their eyes time to practice the technique.

It is the author's evidence-based opinion that USG represents the future of brachial plexus blocks. The dissemination of USG techniques is currently hindered by the limited availability of good quality ultrasound machines in many anesthesia services, and by the limited dissemination of the knowledge needed to perform USG blocks. The decreasing price and increasing utility of ultrasound systems capable of producing good quality images are inciting more anesthesia services to equip themselves with this technology. In parallel with the increasing availability of ultrasound systems, many articles, booklets, websites, and seminars describing USG blocks are now being produced. As the advantages of USG blocks over blind brachial plexus anesthesia techniques become better appreciated by anesthesiologists and patients alike, the neurostimulator may eventually join the ether mask and sharp bevel spinal needle in the anesthetic dustbin.

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References

1. Auroy Y, Narchi P, Messiah A, et al. Serious complications related to regional anesthesia: results of a prospective survey in France. *Anesthesiology* 1997;87:479-86.
2. Grant SA, Nielsen KC, Greengrass RA, et al. Continuous peripheral nerve block for ambulatory surgery. *Reg Anesth Pain Med* 2001;26:209-14.
3. Capdevila X, Barthelet Y, Biboulet P, et al. Effects of perioperative analgesic technique on the surgical outcome and duration of rehabilitation after major knee surgery. *Anesthesiology* 1999;91:8-15.
4. Klaastad O, Lilleas FG, Rotnes JS, et al. Magnetic resonance imaging demonstrates lack of precision in needle placement by the infraclavicular brachial plexus block described by Raj et al. *Anesth Analg* 1999;88:593-8.
5. Mukherji SK, Wagle A, Armao DM, Dogra S. Brachial plexus nerve block with CT guidance for regional pain management: initial results. *Radiology* 2000;216:886-90.
6. Nishiyama M, Naganuma K, Amaki Y. A new approach for brachial plexus block under fluoroscopic guidance. *Anesth Analg* 1999;88:91-7.
7. Carles M, Pulcini A, Macchi P, et al. An evaluation of the brachial plexus block at the humeral canal using a neurostimulator (1417 patients): the efficacy, safety, and predictive criteria of failure. *Anesth Analg* 2001;92:194-8.
8. Fanelli G, Casati A, Garancini P, Torri G. Nerve stimulator and multiple injection technique for upper and lower limb blockade: failure rate, patient acceptance, and neurologic complications. Study Group on Regional Anesthesia. *Anesth Analg* 1999;88:847-52.
9. Kinirons BP, Bouaziz H, Paqueron X, et al. Sedation with sufentanil and midazolam decreases pain in patients undergoing upper limb surgery under multiple nerve block. *Anesth Analg* 2000;90:1118-21.
10. Perlas A, Chan VW, Simons M. Brachial plexus examination and localization using ultrasound and electrical stimulation: a volunteer study. *Anesthesiology* 2003;99:429-35.
11. Chan VW. Nerve localization-seek but not so easy to find? *Reg Anesth Pain Med* 2002;27:245-8.

12. Kapral S, Krafft P, Eibenberger K, et al. Ultrasound-guided supraclavicular approach for regional anesthesia of the brachial plexus. *Anesth Analg* 1994;78:507-13.
13. Chan VW. Applying ultrasound imaging to interscalene brachial plexus block. *Reg Anesth Pain Med* 2003;28:340-3.
14. Porter JM, McCartney CJ, Chan VW. Needle placement and injection posterior to the axillary artery may predict successful infraclavicular brachial plexus block: a report of three cases: [La position de l'aiguille et l'injection posterieure a l'artere axillaire peuvent predire la reussite d'un bloc sous-claviculairedu plexus brachial: presentation de trois cas]. *Can J Anaesth* 2005;52:69-73.
15. Dingemans E, Williams SR, Arcand G, et al. Neurostimulation decreases the success rate of ultrasound-guided infraclavicular block. (In preparation).
16. Sandhu NS, Capan LM. Ultrasound-guided infraclavicular brachial plexus block. *Br J Anaesth* 2002;89:254-9.
17. Arcand G, Williams SR, Chouinard P, et al. Ultrasound-guided infraclavicular versus supraclavicular block. (Accepted for publication).
18. Sandhu NS. Ultrasound imaging of brachial plexus. *Anesthesiology* 2004;100:1325-6; author reply 6-7.
19. Sites BD, Gallagher JD, Cravero J, et al. The learning curve associated with a simulated ultrasound-guided interventional task by inexperienced anesthesia residents. *Reg Anesth Pain Med* 2004;29:544-8.
20. Schafhalter-Zoppoth I, McCulloch CE, Gray AT. Ultrasound visibility of needles used for regional nerve block: an in vitro study. *Reg Anesth Pain Med* 2004;29:480-8.
21. De Andres J, Sala-Blanch X. Ultrasound in the practice of brachial plexus. *Anesthesia* 2002;27:77-89.
22. Childs SG. Tension pneumothorax: a pulmonary complication secondary to regional anesthesia from brachial plexus interscalene nerve block. *J Perianesth Nurs* 2002;17:404-10; quiz 10-2.
23. Benumof JL. Permanent loss of cervical spinal cord function associated with interscalene block performed under general anesthesia. *Anesthesiology* 2000;93:1541-4.
24. Chan VW, Perlas A, Rawson R, Odukoya O. Ultrasound-guided supraclavicular brachial plexus block. *Anesth Analg* 2003;97:1514-7.
25. Williams SR, Chouinard P, Arcand G, et al. Ultrasound guidance speeds execution and improves the quality of supraclavicular block. *Anesth Analg* 2003;97:1518-23.
26. Greher M, Retzl G, Niel P, et al. Ultrasonographic assessment of topographic anatomy in volunteers suggests a modification of the infraclavicular vertical brachial plexus block. *Br J Anaesth* 2002;88:632-6.
27. Ootaki C, Hayashi H, Amano M. Ultrasound-guided infraclavicular brachial plexus block: An alternative technique to anatomical landmark-guided approaches. *Reg Anesth Pain Med* 2000;25:600-4.
28. Gray AT, Schafhalter-Zoppoth I. Ultrasound guidance for ulnar nerve block in the forearm. *Reg Anesth Pain Med* 2003;28:335-9.
29. Konrad C, Schupfer G, Wietlisbach M, Gerber H. Learning manual skills in anesthesiology: Is there a recommended number of cases for anesthetic procedures? *Anesth Analg* 1998;86:635-9.

Abstract of Interest

Applying ultrasound imaging to interscalene brachial plexus block

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OBJECTIVE: Previous studies have examined ultrasound-assisted brachial plexus blocks, but few have applied this imaging technology to the interscalene region. We report a case of interscalene brachial plexus block using ultrasound guidance to show the clinical usefulness of this technology.

CASE REPORT: A nerve stimulator-guided interscalene block was attempted for arthroscopic shoulder surgery but failed. Subsequent nerve localization was accomplished by ultrasound imaging using a high-frequency probe (5-12 MHz) and the Philips ATL HDI 5000 unit. Ultrasound showed nerves between the scalene muscles, block needle movement at the time of advancement, and local anesthetic spread during injection. Interscalene block was successful after 1 attempt of nerve localization and needle placement.

CONCLUSIONS: Advanced ultrasound technology is useful for nerve localization and can generate brachial plexus images of high resolution in the interscalene groove, guide block needle placement and advancement in real time to targeted nerves, and assess adequacy of local anesthetic spread at the time of injection. Ultrasound imaging guidance can potentially improve success during interscalene brachial plexus block.

Reg Anesth Pain Med 2003;28(4):340-3.

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