Ultrasound versus peripheral nerve stimulator for peripheral nerve blockade: Pros and cons

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The use of ultrasound to perform peripheral nerve blocks is a relatively new technique that is rapidly gaining in popularity over the more traditional techniques of peripheral nerve stimulators and paresthesia. Lack of suitable ultrasound machines delayed the introduction of this modality into common practice until early 2000. Technological advances have resulted in the availability today of numerous ultrasound machines that are portable, decreasing in price although still not inexpensive, and have all the features that are necessary to perform ultrasound-guided regional anesthesia (USG-RA). It is interesting to note that the current debate regarding which technique is “better”, ultrasound or PNS, is similar to the previous comparison between paresthesia and the PNS. The latter is a debate that has continued for decades and is still without a clear-cut answer. The objective of this lecture is to discuss the evidence for and against the use of USG-RA and to determine whether our current knowledge can support the use of US over that of the PNS.

The anesthesia literature has been inundated with articles, case reports and letters promoting, and occasionally questioning the use of ultrasound-guided regional anesthesia (USG-RA)\(^1\). Proponents of this technique\(^2\) argue that the use of ultrasound has the following advantages:

1. Anatomical structures, for example nerves, blood vessels, the pleura, can be easily identified, as can unexpected anatomical variations and abnormalities.
2. The insertion and placement of the block needle can be visualized in real time with the result that: (a) unintentional penetration of structures such as blood vessels and the pleura can be avoided and/or recognized, and (b) positioning and, if required, repositioning of the needle is performed under direct vision and in real time as opposed to blind redirection and repositioning of the needle with the PNS. This should result in decreased performance time and less patient discomfort.
3. Penetration of a nerve sheath (e.g. the brachial plexus sheath) is in most cases easily visualized as indicated by initial indentation of the sheath followed by sudden recoil of the sheath during needle penetration.
4. Injection of the local anesthetic solution is easily visualized, in real time as is the spread of the local anesthetic within the sheath and around the nerves. As a result, the controversy regarding the presence or absence of septa within the brachial plexus sheath becomes a non-issue as any nerve(s) that are not surrounded by local anesthetic during the initial injection can be identified. These nerves can then be blocked individually by simple repositioning the block needle and injecting an additional bolus of local anesthetic.
5. Individual nerves can be identified and blocked anywhere along their pathway from core to periphery.
6. Approaches that had fallen into disfavor due to potential complications have regained their popularity, i.e. the supraclavicular brachial plexus block.
7. It has been suggested that peripheral nerve blocks can be safely performed in patients under general anesthesia with the use of ultrasound, however this issue is controversial.

As a result of the benefits described above, the time to perform the block as well as the onset time is decreased, the success rate is increased, the complication rate decreased, and, as a result, overall patient satisfaction is improved.

The primary argument advanced against the use of ultrasound is that the cost of the US machine cannot be justified as the benefits attributed to USG-RA over more traditional techniques have not materialized when performed by a skilled regional anesthesiologist. In addition, the lack of ultrasound machines at many institutions will place recently graduated anesthesia residents, trained only in the use of ultrasound and without PNS experience, at a disadvantage on entering...
the private practice(1). This author, amongst many other regional anesthesiologists, totally disagrees particularly with the latter argument(2).

The objective of this lecture is to present the evidence in support of the use of ultrasound and to add a word of caution that its use does not guarantee a 100% success rate, nor is it free of complications(3,4). The studies supporting the use of ultrasound have been arbitrarily divided into sections despite the fact that many of the studies address various benefits.

ANATOMY-RELATED BENEFITS

An issue frequently raised against the use of regional anesthesia in general is that, even in experienced hands, the success rate is rarely 100%. One of the reasons for this is that the anatomy of the human body is variable and these variations are unrecognizable during the performance of either a paresthesia or PNS technique, both of which depend on surface landmarks and blind needle insertion. Harry et al. demonstrated that the brachial plexus is situated between the face landmarks and blind needle insertion. Harry et al. dem-

An interesting collateral benefit of the use of US is the occasional diagnosis of unexpected pathology unrelated to the nerve block. Sutin et al. reported the incidental finding of a previously undiagnosed femoral vein thrombosis in a patient with a fractured femur in whom an US-guided femoral nerve block was being performed(7-9).

Orebaugh et al. compared the time taken by residents in a training program to perform various blocks (interscalene, axillary, femoral and popliteal) with either a PNS alone or a PNS aided by US(11). The authors reported that US-aided blocks were faster to perform (median = 1.6 min vs 6.5 min, P = < 0.001), required less needle insertions (median = 2 vs 6, P = < 0.001), and resulted in fewer blood vessel punctures (P = 0.03).

Sites et al., compared the time to perform an axillary block utilizing a transarterial technique (TA) versus ultrasound (US) as well as the success rate(12). The US group demonstrated a reduction in performance times vs. Group TA (7.9 ± 3.9 min vs 11.1 ± 5.7 min, P < 0.05) as well as a significantly greater success rate. The TA group sustained more failures defined as conversion to general anesthesia or the inability to localize the artery (TA eight patients (29%) vs Group US in which 0 patients required conversion to general anesthesia (0%) (P < 0.01).

In a prospective study, Williams et al assessed the quality, safety, and execution time of supraclavicular blocks of the brachial plexus using ultrasonic guidance and neurostimulation compared with a supraclavicular technique that used anatomical landmarks and neurostimulation(13). At 30 min 95% of patients in the US group and 85% of patients in the NS group 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.

Casati et al compared conventional “landmark-based” plexus anaesthesia to an ultrasound-guided approach in the performance of interscalene and axillary blocks(14). The use of ultrasound significantly improved the onset and completeness of sensory (P = 0.011) and motor (P = 0.002) block. Ultrasound guidance also significantly reduced P = 0.012) the incidence of paraesthesia during the performance of the blocks.

Marhofer et al evaluated whether ultrasound facilitates the approach for 3-in-1 blocks(16). Forty patients undergoing hip surgery after trauma were randomly assigned to either an ultrasound (US) or a nerve stimulator (NS) group. The onset of sensory blockade was significantly shorter in Group US compared with Group NS (US 16 ± 14 min, NS 27 ± 16 min, P < 0.05). The quality of the sensory block after injection of the local anesthetic was also significantly bet-
ter in Group US compared with Group NS (US 15% ± 10% of initial value, NS 27% ± 14% of initial value, P < 0.05). A good analgesic effect was achieved in 95% of the patients in the US group and in 85% of the patients in the NS group. Incidental arterial puncture was observed in 3 patients, all in the NS group. They concluded that an US-guided approach for 3-in-1 block reduces the onset time, improves the quality of the sensory block and minimizes the risks associated with this regional anesthetic technique.

In a study in pediatric patients, Marhofer et al. reported that compared against the nerve stimulator, the use of US was found to be of benefit during the performance of infraclavicular blocks\(^{[17]}\). Forty children scheduled for arm and forearm surgery underwent infraclavicular brachial plexus blocks by either nerve stimulation or ultrasound visualization. Direct ultrasound visualization was successful in all cases and was associated with significant improvements when compared with the use of nerve stimulation: lower visual analogue scores during puncture (p = 0.03), shorter mean (median) sensory onset times (9 (5-15) min vs 15 (5-25) min, p < 0.001), longer sensory block durations (384 (280-480) min vs 310 (210-420) min, p < 0.001), and better sensory and motor block scores 10 min after block insertion. In addition, the pain associated with nerve stimulation due to muscle contractions at the time of insertion was eliminated.

Ultrasound guidance, with or without concomitant nerve stimulation, has also been shown to significantly improve the success rate of axillary brachial plexus block\(^{[18]}\). Patients undergoing elective hand surgery were randomly assigned to one of three groups. Axillary blocks were performed using three motor response endpoints in the nerve stimulator (NS) group, real-time ultrasound guidance in the ultrasound (US) group and combined ultrasound and nerve stimulation in the USNS group. A successful block was defined as complete sensory loss in the median, radial and ulnar nerve distribution by 30 min. Block success rate was higher in groups US and USNS (82.8% and 80.7%) than group NS (62.9%) (P = 0.01 and 0.03 respectively). Fewer patients in groups US and USNS required supplemental nerve blocks and/or general anesthesia. In addition, postoperatively, axillary bruising and pain were reported more frequently in group NS.

A similar benefit was reported by Sites et al comparing an axillary block performed by either a transarterial technique (Group TA) or an ultrasound-guided perivascular approach (Group US)\(^{[12]}\). Group TA sustained more failures defined as conversion to general anesthesia or the inability to localize the artery [Group TA eight patients (29%) vs. Group US in which 0 patients required conversion to general anesthesia (0%) P < 0.01]. Group US demonstrated a reduction in performance times vs Group TA (7.9 ± 3.9 min vs 11.1 ± 5.7 min, P < 0.05). An additional safety feature is associated with the ability to achieve a successful block with a reduced volume of local anesthetic.

### INCREASED SAFETY

USG-RA may increase the safety of regional anesthesia in a number of ways. Lack of the characteristic spread of local anesthetic on initiation of the injection should result in the immediate reassessment of correct needle placement as the needle may be intravascular or intraneural. Abnormal distribution of the local anesthetic implies that the needle is not correctly positioned either within the plexus sheath or in close-enough proximity to a peripheral nerve. Significantly smaller volumes of local anesthetic can be used as individual nerves can be identified and blocked individually.

Marhofer et al evaluated whether US guidance for 3-in-1 blocks reduces the amount of local anesthetic required for a successful block compared to NS guidance\(^{[19]}\). Sixty patients undergoing hip surgery were randomly assigned to three groups of 20 patients each. In group A, the 3-in-1 block was performed using US guidance with 20 mL 0.5% bupivacaine. Group B received 20 mL 0.5% bupivacaine, and group C received 30 mL 0.5% bupivacaine during NS guidance. The overall success for the 3-in-1 block in group A was 95% and in groups B and C 80%. Onset time was significantly shorter in the US-guided group compared with both NS-guided groups (group A 13 ± 6 minutes; group B 27 ± 12 minutes; and group C 26 ± 13 minutes; P < .01 to groups B and C). Quality of sensory block was significantly better in group A (4% ± 5% of initial value) compared with groups B and C (group B 21% ± 11% of initial value, P < .01 to group A; group C 22% ± 19%, P < .01 to group A). The authors concluded that the amount of local anesthetic for 3-in-1 blocks can be reduced by using US guidance compared with the conventional NS-guided technique.

With a similar goal in mind, Casati et al. tested the hypothesis that ultrasound guidance may reduce the minimum effective anaesthetic volume (MEAV50) of ropivacaine 0.5% required to block the femoral nerve compared with nerve stimulation guidance\(^{[20]}\). Sixty patients undergoing knee arthroscopy were randomly allocated to receive a femoral nerve block with ropivacaine 0.5% using either nerve stimulation or ultrasound guidance. The volume of the injected solution was varied for consecutive patients based on an up-and-down staircase method according to the response of the previous patient. The initial volume was 12 mL. A double-blinded observer evaluated the occurrence of complete loss of pinprick sensation in the femoral nerve distribution, with concomitant block of the quadriceps muscle: positive or negative responses within 30 min after the injection determined a 3 mL decrease or increase for the next patient.
respectively. The mean (sd) MEAV50 for femoral nerve block was 15.4 mL (95% CI, 7-23 mL) in group US and 26.4 mL (95% CI, 19-33 mL) in group NS (P = 0.002). The effective dose in 95% of cases (ED95) was 22 mL (95% CI, 13-36 mL) in group US, and 41 mL (95% CI, 24-66 mL) in group NS. Thus, US guidance provided a 42% reduction in the MEAV of ropivacaine 0.5% required to block the femoral nerve as compared with the needle stimulation guidance.

The sensitivity of a paresthesia or PNS technique, as tools for nerve localization was studied by Perlas et al(21). After needle-to-nerve contact was confirmed by ultrasonography, the patient was requested to report the presence of paresthesia, and a nerve stimulator as used to seek a motor response with a stimulating current of 0.5 mA or less. Paresthesia was found to be 38.2% sensitive and motor response was 74.5% sensitive (at 0.5 mA) for detection of needle-to-nerve contact. These findings suggest that needle-to-nerve contact may frequently occur without the subjective report of a paresthesia or an objective motor response. These findings add substance to the pro and con debate between the use of paresthesia versus the PNS, in which numerous studies have demonstrated that an unintentional paresthesia can be elicited without a muscle twitch (motor response) despite the use of a PNS. This in turn may result in inappropriate repositioning of the needle with the possibility of increased patient discomfort at best, and/or nerve injury at worst(22-25).

Utilizing ultrasound to perform supraclavicular blocks, Beach et al. demonstrated that in 13.5% of cases nerve stimulation failed to elicit a motor response despite correct needle location within the brachial plexus sheath(26).

LESS PATIENT DISCOMFORT

The fact that USG-RA can be performed more efficiently and with less manipulation of the needle suggests that patient discomfort during block performance should be reduced. Hu et al. addressed the issue of patient comfort during regional anesthesia. They included amongst their recommendations that the nerve stimulator technique should be preferred over the paresthesia technique(27). In response, O’Sullivan, referring to studies by Marhofer, et al. stressed the benefits of ultrasound over the PNS in that uncomfortable muscle twitches are avoided with the US-guided technique(17,28,29). Plunkett et al placed a supraclavicular continuous peripheral nerve block in a combat-injured soldier whose injuries precluded the use of a PNS(30).

Casati et al, in comparing an axillary brachial plexus block with either US or a PNS and multiple injection technique reported a median (range) number of needle passes of 4 (3-8) in the US group versus 8 (5-13) in group NS (P = 0.002)(15). These results support the argument that patient discomfort is reduced by decreasing the number of needle insertions.

In comparing the efficacy of ultrasound, combined with nerve stimulation, to locate and block the sciatic nerve at the lateral midfemoral level compared to nerve stimulation alone, Domingo-Triado et al. reported that the success of sciatic nerve location at the first attempt was significantly more frequent in the US group than in the nerve stimulator group (76.6% versus 41.9%; P < 0.001)(31). The quality of the sensory block and the tolerance to the pneumatic tourniquet were also significantly better in the US group (P < 0.01). They concluded that ultrasound combined with nerve stimulation improved the quality of the sensory block and the tolerance to the pneumatic tourniquet, and reduced the number of attempts to perform sciatic nerve blockade at the midfemoral level.

AVOIDANCE OF COMPLICATIONS

The avoidance of intraneural injections is a primary concern during the performance of regional anesthesia. Severe paresthesia and/or pain on injection, inability to inject or high resistance to injection(32,33) are all regarded as possible indicators of intraneural placement of the needle. Use of a PNS does not guarantee avoidance of nerve puncture(22,23,34). Ultrasound has potentially added an additional layer of safety in that the needle as well as the nerves are easily visualized thus potentially reducing the incidence of nerve penetration by the needle. However, the occurrence of intraneurale placement of the needle has not been eliminated. Correct needle placement within the plexus sheath and outside of the nerve results in the spread of local anesthetic that is characteristic and can be visualized in real time. On the other hand, a number of studies have reported on the image obtained during the initial phase of an intraneurale injection i.e. expansion of the nerve with eventual rupture of the epineurium. Observation of the initial spread of 1 cc of local anesthetic can serve as an early warning sign of an intraneurale injection(35-37).

In an interesting report by Bigeleisen, the incidence of apparent nerve puncture and intraneurale injection of local anesthetic was prospectively studied in 26 patients undergoing ultrasound-guided axillary brachial plexus block(35). Qualitative sensory and quantitative motor testing were performed before and 5 and 20 min after block placement. At a follow-up 6 months after the blocks, the patients were examined for any neurological deficit. In 22 out of 26 patients nerve puncture of at least one nerve occurred, and 21 of 26 patients had an intraneurale injection of at least one nerve. In the entire cohort, 72 of a total of 104 nerves had intraneurale injection. Sensory and motor testing before and 6 months after the nerve injections were unchanged. The author concludes that under the conditions of this study, puncturing of the peripheral nerves and apparent intraneur-
rational injection during axillary plexus block did not lead to a neurologic injury.

**REJUVENATION OF AN UNPOPULAR BLOCK**

Although the supraclavicular approach to the brachial plexus has numerous advantages over the infraclavicular and axillary approaches, i.e. high success rate with a single injection and small volume technique as well as a rapid onset, its popularity declined based on the risk of a pneumothorax and injury to the subclavian artery. With the introduction of ultrasound, this approach has gained in popularity and is certainly this author’s preference over the infraclavicular and axillary approaches for surgery below the shoulder. The plexus, artery, first rib and pleura are easily visualized as well as the course of the needle and the spread of local anesthetic. Williams et al(13) and Kapral et al(38) demonstrated the benefits of the use of ultrasound over conventional techniques, and Soares et al describe their technique of optimizing success rate(39).

**THE “DISADVANTAGES” OF ULTRASOUND**

The major criticism leveled against the use of ultrasound revolves around the cost and availability of ultrasound machines. This author favors the smaller, portable machines, however, even these machines are expensive with prices ranging between approximately $20,000 and $50,000 depending on the make, model and available options. In addition, the performance of USG-RA requires 2 individuals as the operator holds the probe in one hand and the needle in the other, therefore a second person is required to inject the local anesthetic (although Fredrickson et al reported successful continuous interscalene analgesia for ambulatory surgery in 300 patients in which a single operator placed nonstimulating catheters using a combination of ultrasound and nerve stimulation)(40). These additional costs may be partially offset by an increase in the number of blocks performed (decreased time to perform the block plus shorter onset time)(41), a decrease in supplementation or conversion to general anesthesia (increased success rate), and a decrease in complications. An increase in success rate may result in further cost reduction due to less postoperative opioid-related side effects, better postoperative pain control and more rapid discharge from the PACU/ASU.

An issue that does need to be addressed involves the errors that occur due to inexperienced use of the ultrasound technique. Sites et al. videotaped six residents during the performance of 536 ultrasound-guided nerve blocks(42). During the procedure 398 errors occurred of which failure to visualize the needle and unintentional probe movement were the commonest. In addition, 5 previously unrecognized “quality compromising patterns of behavior” were recognized. These included failure to recognize local anesthetic maldistribution as well as intramuscular location of the needle tip, failure to correlate the sidedness of the patient with that of the machine image, poor choice of needle insertion site and fatigue. These are issues that need to be vigorously addressed during training and simulation programs.

The use of USG-RA is still a relatively new technique with the result that numerous artifacts, both acoustic and anatomic exist that can result in prolonged procedure times, failed blocks, and patient injury(43). Sites et al. define two major categories of imaging artifacts: (1) acoustic, i.e. errors in presentation due to incorrect use of machine controls such as the gain, depth, and frequency, and (2) anatomic, i.e. errors in interpretation (pitfall error) due to misinterpretation of an actual physical structure(44,45).

In conclusion, it is this author’s opinion that the benefits of USG-RA far outweigh the few “disadvantages” described above. It should be stressed that the use of ultrasound does not preclude the use of a nerve stimulator as an additional resource to confirm correct needle placement, identify a specific nerve, or simply as an educational tool during the phase of conversion to ultrasound. The final objective is to provide safe, effective and efficient regional anesthesia with minimal discomfort to the patient.

**REFERENCES**


41. Sandhu NS, Sidhu DS, Capan LM. The cost comparison of infrACLavicular continuous peripheral nerve block in a wounded soldier: when ultrasound is the only option. Br J Anaesth 2006;97:715-717.


