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# The impact of local anesthetic distribution on block onset in Ultrasound-guided interscalene block

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## Abstract

**Background—**Recent investigations of local anesthetic distribution in the lower extremity have revealed that completely surrounding the sciatic nerve with local anesthetic provides the advantage of more rapid and complete anesthesia in the territory served by the nerve. We hypothesized that a pattern of distribution which entirely envelops the targeted nerve roots during interscalene block would provide similar benefits of more rapid anesthesia onset.

**Methods—**During interscalene block guided by ultrasound with nerve-stimulator confirmation, the pattern of local anesthetic distribution was recorded and later classified as complete or incomplete envelopment of the visible nerve elements in 50 patients undergoing ambulatory shoulder arthroscopic surgery. The pattern was then compared to the extent of block set-up at predetermined intervals, as well as to postoperative pain levels and block duration.

**Results—**22 patients (44%) had complete envelopment of the nerves in the plane of injection during ultrasound imaging of the interscalene block. There was no difference in the fraction of blocks that were fully set-up at 10 minutes with regards to complete or incomplete envelopment of the nerves by local anesthetic. All of the patients had complete set-up of the block by 20 minutes. In addition, the postoperative pain levels and duration of block did not vary among the two groups with complete versus incomplete local anesthetic distribution around the nerves.

**Conclusion—**The presence or absence of complete envelopment of the nerve elements in the interscalene groove by local anesthetic did not determine the likelihood of complete block effect at predetermined time intervals after the procedure.

## Introduction

Interscalene brachial plexus block is increasingly used for pain control related to shoulder surgery, [1] and is facilitated by the use of ultrasound guidance.[2] In general, ultrasound permits more rapid block performance, lower volumes of local anesthetic, higher success rates and even improved duration.[3] However, the exact site of optimal placement of local anesthetic in the interscalene region is not clearly defined.[4]

Recent investigations of local anesthetic distribution in the lower extremity have revealed that completely surrounding the sciatic nerve with local anesthetic provides the advantage of

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more rapid and complete anesthesia in the territory served by the nerve.[5] However, the anatomic conformation of nerve elements and surrounding fascial planes is distinctive in the interscalene region, as compared to other sites of peripheral nerve blockade. We evaluated the spread of local anesthetic solution as evident on ultrasound imaging during interscalene block and hypothesized that a pattern of distribution which entirely envelops the targeted nerve roots at interscalene levels would provide similar benefits of more rapid anesthesia set-up.

## Methods

This study was approved by the University of Pittsburgh Institutional Review Board. Patients undergoing Interscalene Block (ISB) for ambulatory shoulder surgery with ultrasound and nerve stimulator guidance were enrolled after informed consent was obtained. Included were ASA physical status 1-3 status patients undergoing shoulder surgery, who were eligible for an ISB. Exclusion criteria consisted of pregnant patients, ASA physical status 4 or 5, any neuropathic processes or nerve injury involving the upper extremities, allergy to amide local anesthetics, active infection at the site of the block, inability to turn head to facilitate block placement, or any other contraindication to ISB. The patients were evaluated preoperatively, including a neurologic examination of the extremity to be blocked.

Population variables collected included age, side of surgery, type of surgery, gender, height and weight. The primary outcome measure was the fraction of ISB that were completely set-up at 10 minutes. The secondary outcome measures were block failure rate (need for supplemental placement of local anesthetic at the interscalene or other site, or a conversion to a general anesthetic), immediate post operative pain scores, and block duration. Patients underwent an ultrasound-guided ISB after monitors were placed, and oxygen and sedation were administered. Sedation was achieved through a peripheral intravenous line and consisted of 1-2 mg midazolam and 50 mcg fentanyl. The interscalene area was identified and prepared with chlorhexidine and alcohol. With the transducer held in a coronal-oblique position, the brachial plexus was imaged at the supraclavicular level and then followed cephalad until 2 or 3 nerve fascicles were evident in the space between the scalene muscles. At this level, 1 ml of 1% lidocaine was injected in the skin lateral to the probe, and a 5 cm, 22- gauge stimulating needle ( B Braun, Bethlehem, PA) was inserted with in-plane ultrasound guidance (S-Nerve, Sonosite, Bothell, WA). The needle was connected to a Stimuplex nerve stimulator (B Braun), which was set at 2 Hz, with 0.5 milliamperes of current, and a pulse duration of 0.1 msec. The needle was advanced toward the visible nerve fascicles which were typically those of the C5 and C6 nerve roots. As the tip of the needle passed through the scalene fascia, the nerve stimulator was turned on. The needle advancement was stopped when any brachial plexus motor stimulation was achieved, or the tip was clearly visualized to lie in the groove, adjacent to, or between the visible fascicles. The stimulator current was reduced to determine the threshold of stimulation and then was shut off. If no twitch was produced with the needle in this position, the current was increased until a motor response was achieved. The needle tip was not moved during this process. A solution of 20 ml of ropivacaine 7.5 mg/ml was injected at an approximate rate of 5ml per 15 seconds with aspiration every 5ml to monitor for intravascular injection.

A video of the ultrasound image of the block procedure was retained for later analysis of the fluid distribution in the interscalene groove. In addition, immediately after injection of the local anesthetic, the transducer was moved to the supraclavicular area to assess local anesthetic spread distal to the site of injection, along with any enhancement around the plexus in this area, highlighting the superior trunk.

When the block was completed, the extent of anesthesia in the shoulder region was evaluated after 5, 10, and 20 minutes had elapsed. Using a 3 point scoring system (2= normal sensation, 1= partial/reduced sensation, 0= no preserved sensation), sensory nerve function was evaluated at C4 (cape region), C5 (over the deltoid), and C6 (thumb) dermatomes, for anesthesia to pinprick and cold temperature. Motor function was similarly evaluated using a 3 point score (2= normal strength, 1= reduced/partial strength, 0=no motor function) for deltoid motor (shoulder flexion) and biceps motor (elbow flexion) function. If motor or sensory function was preserved in these regions at 20 minutes after the block, 5ml of supplemental local anesthetic of the same solution was delivered to the same area of the brachial plexus in the interscalene groove under ultrasound guidance. After the block was judged to be completely set-up, patients were taken to the operating room. All surgeries were conducted arthroscopically, in beach-chair position, with interscalene block accompanied by propofol sedation, with spontaneous respiration and supplemental oxygen by face mask.

Postoperative pain at the incision sites was noted on arrival in the PACU. Reports of pain at non-incision sites, such as low back pain, or pain in the breast/chest area apparently related to swelling were not attributed to block inadequacy. The patients were called at 24 hours and queried as to when pain was first noted as an index of block duration. If contact was not established at 24 hours, a call was attempted at 48 hours. All patients were successfully contacted postoperatively.

After all the clinical data was collected, the de-identified ultrasound video clips of block performance were assessed by one of the authors **(MK),** who was not aware of the clinical characteristics of the blocks. The distribution of the local anesthetic was rated as either “complete” (Group C) or “incomplete” (Group I). A complete distribution block was defined as local anesthetic solution entirely surrounding the visible nerve roots on the medial and lateral sides as well as between them (Figure 1). An incomplete distribution was defined as local anesthetic collecting on only one side of the roots, or between them, but not encompassing them on all sides (Figure 2). The completeness of anesthesia at the designated times, the block failure rate (need for supplemental placement of local anesthetic at the interscalene or other site, or a conversion to a general anesthetic), the immediate post operative pain scores, and the block duration were collected for comparison of Group C and Group I.

## Statistical analysis

For the proposed study the primary outcome was defined as the measure of function ten minutes after the injection. The outcome was scored as 0 for no function, 1 for mild function and 2 for normal function, for both motor and sensory aspects of the relevant nerves. Comparison was then performed of those with completely surrounded nerves to those with incompletely surrounded nerves, with regard to complete loss of function at the predetermined time intervals.

Prior studies report an approximately 30% difference in block onset time for complete versus incomplete circumferential distribution of the sciatic nerve in the popliteal fossa with local anesthetic solution [5]. We a priori chose 10 minutes as a clinically meaningful block onset time, and calculated that at least 19 patients would be necessary in each group in order to detect a 30% higher rate of complete block effect at this time interval, for Group C as compared to Group I. . This is assuming a type I error rate of .05, a type II error rate of 20%, a one-sided alternative hypothesis (that the partially surrounded site has a lower percentage with complete block effect), and that the rate of subjects with no functioning at 10 minutes after the injection among those with a completely surrounded site would be 95%.

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To analyze the primary outcome, a one-tailed Fisher's exact test was utilized. In order to determine if there was potential confounding, the baseline characteristics of those with complete versus incomplete surrounding were compared. Chi-square tests were used for discrete variables and a Wilcoxon test was used for continuous characteristics. Secondary discrete outcomes were compared using a chi-square test, while a Wilcoxon was used to test secondary continuous outcomes. In addition, as a qualitative outcome measure, the appearance of the superior trunk at the supraclavicular region after the block was assessed with ultrasound imaging for evidence of envelopment by local anesthetic solution.

## Results

There were no significant differences between Group C and Group I, in terms of demographic factors (Table 1). Patient surgical types and duration are detailed in Table 2. Of the 22 patients in Group C, 12 (55%; 95% CI 0.34-0.73) had complete block set-up by 10 minutes after the block, while 12 (43%, 95% CI 0.26-0.61) of the 28 patients in Group I had a complete block by this time (p=0.57) (Table 3). All of the patients had complete set-up of the block by 20 minutes.

Among secondary outcome measures, there was no difference among groups in the fraction of patients experiencing pain in the PACU, in stimulation threshold (Table 2) or in block duration (Table 3). There were no blocks that required supplementation or that required implementation of general anesthesia. Further, there were no reported complications when the patients were called at 24-48 hours after the surgical procedure. After the injection was completed, scanning at the supraclavicular region revealed highlighting and apparent surrounding of the superior trunk with the injected solution in all of the cases.

## Discussion

In this investigation, we found that the distribution pattern of local anesthetic, in relationship to the visible nerve elements of the brachial plexus in the interscalene groove, did not determine the fraction of blocks fully established at 10 minutes, nor the success or duration of the resultant nerve block. Specifically, our hypothesis that a flow pattern which completely surrounds the nerve elements would result in a significantly more rapid onset pattern of clinical importance was not supported by the data.

While ISB is in widespread use, both with and without ultrasound guidance, the optimal placement and spread of local anesthetic solution is uncertain. Some authors have cited the need for further research into this question in editorials,[4] emphasizing that two possibilities for success exist: insertion of the needle well into the plexus, among the nerve elements, with subsequent injection which would presumably be widespread and surround all of the visible elements, or a less invasive approach, in which the needle tip is merely approximated to the nearby nerve column in the interscalene groove and injection commenced at that point. This would theoretically result in an elliptical pattern of local anesthetic spread, apparently confined to only one side of the visible nerve elements. Spence, et al, addressed this quandary in a subsequent trial in which patients were randomized to an “intra-plexus” injection group and a “peri-plexus” group.[6] The authors found no difference in their primary outcome measure (block onset time), though they did note a prolongation of block duration by nearly 2 hours in the “intra-plexus” group, which represented a secondary outcome measure.

In a similar investigation, Plante conducted directed injection of local anesthetic for ISB specifically to the C5 nerve root or the C6 nerve root, and evaluated the impact of each type of injection on the resultant block characteristics.[7] While the overall adequacy of the blocks for shoulder surgery were not different, there was significantly greater spread of local anesthetic effect to the more inferior portion of the brachial plexus when the injection was located near the C6 root, with a greater degree of distal (and medial) arm anesthesia. Onset times and duration were not different between the two groups, however. In a comparison of ultrasound-guided ISB with nerve stimulator guidance alone, Kapral et al [2] reported a more rapid onset and more complete upper extremity blockade with ultrasound use, along with a higher degree of success for blockade of the desired dermatomes for shoulder surgery. The authors' methodology was such that, if the flow pattern of local anesthetic seen on ultrasound did not appear to surround all of the visible nerve elements, the needle was moved to accomplish this objective.

The anatomy of the interscalene groove and the nerves within it are distinct from peripheral nerves in many other areas of the body. The fascial confines, closely bordering a number of aligned nerve elements, are unlike a peripheral nerve or group of nerves bordered by muscular structures or within a neurovascular bundle. In particular, it is difficult to distinguish the fascia lining the scalene muscles from the epineurium of the nerve elements [8] and also to determine whether a series of hypoechoic nodules representing the nerve roots have come together into a trunk, bounded by a single epineurium.[9] This may have implications for the spread of injected solutions, particularly if they are sequestered within the epineurium. In addition, the fascial septations that have been described at more distal levels of the brachial plexus [10,11] do not appear to be present in the interscalene groove, so that flow between the lining fascia and the epineurium of nerve elements (whether roots or trunks) should be less constrained.

The assessment of local anesthetic spread patterns on 2-dimensional ultrasound may represent a disadvantage. Since a static position of the ultrasound probe during video acquisition represents only one plane, any spread proximal or distal to that plane, and its patterns related to the nerve elements, will not be apparent. As shown in figure 2, the amount of spread in two dimensions may appear deceptively small. However, sequestration of the solution in one area in the image plane may not represent what is occurring in other planes, and would be better defined by 3-dimensional viewing capabilities. In fact, though it was not a quantitative outcome variable, we assessed the appearance of the superior plexus elements distal to the injection site, at the suprascapular level, just after injection was complete. We found in all cases that the superior trunk was distinct, highlighted and appeared to be completely surrounded by local anesthetic solution, even in those patients in whom the spread at the injection plane was clearly confined to one side of the nerves. This may explain the lack of distinction of clinical effects of the various patterns of local anesthetic distribution that we observed in a single imaging plane on ultrasound visualization.

Other limitations of the study include the volume of local anesthetic utilized, which is consistent with our usual practice, though larger volumes (which often reflect practice in non-ultrasound guided circumstances), may have had a greater degree of spread around the nerves. The use of ultrasound has permitted the use of ever-lower volumes of local anesthetics; volumes as low as 5-10 ml may have significantly lesser patterns of spread, but nonetheless have provided successful interscalene brachial plexus block.[4, 7] Also, the precise rate of injection of local anesthetic was not controlled in our study. The rate was intentionally slow, as in our actual clinical practice, though it is possible that the speed of an injection may help to determine the degree of spread visible on ultrasound. In addition, as the comparison groups were not random, it is possible that there were confounding effects which impacted the outcome. Assessment of the baseline characteristics did not reveal confounding effects, however there may have been unmeasured characteristics which impacted the relationship. Finally, we utilized peripheral nerve stimulation as a confirmation of the appropriate needle tip position for injection, which may not reflect the practice of other practitioners who use solely ultrasound visualization to reflect appropriate position.

In conclusion, we found that the presence or absence of complete envelopment of the nerve elements in the interscalene groove, as visualized in a single imaging plane on ultrasound imaging, did not significantly affect the degree of ISB effect at 10 minutes after injection, consistent with other investigations of this phenomenon in the interscalene region. This suggests that it is not necessary to repeatedly move the needle tip within the interscalene groove to achieve an “optimal” spread pattern around the nerves. Therefore, patient discomfort may be lessened during the block, and the time necessary to complete the block may be favorably impacted as well.

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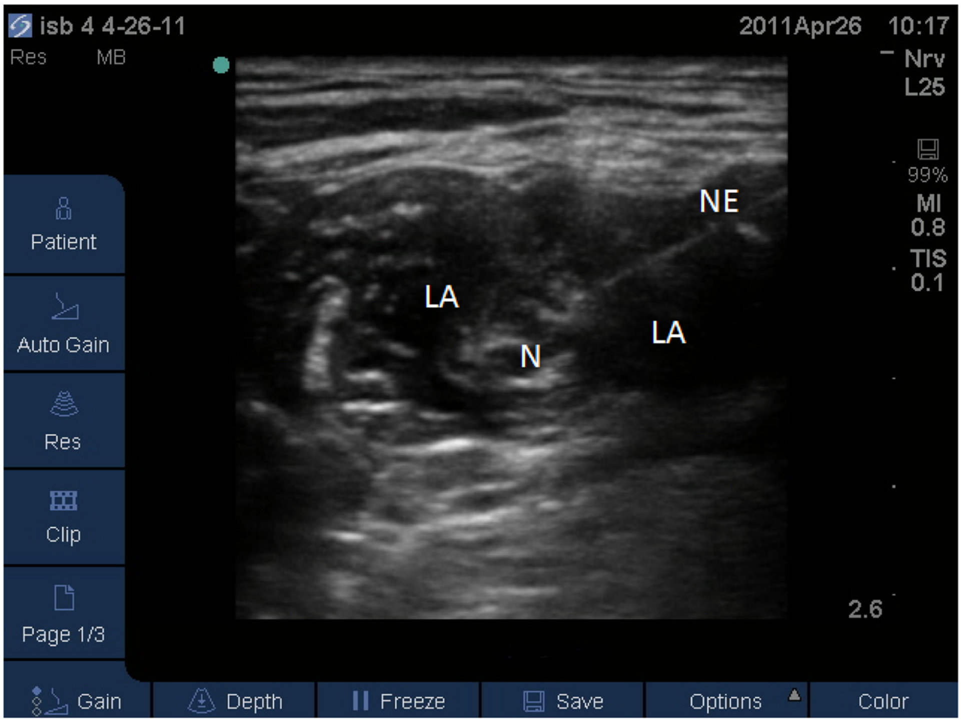


**Figure 1. Ultrasound image of interscalene block illustrating complete envelopment of local anesthetic solution around nerve roots in interscalene groove. (N = nerve root, NE = needle, LA = local anesthetic solution)**

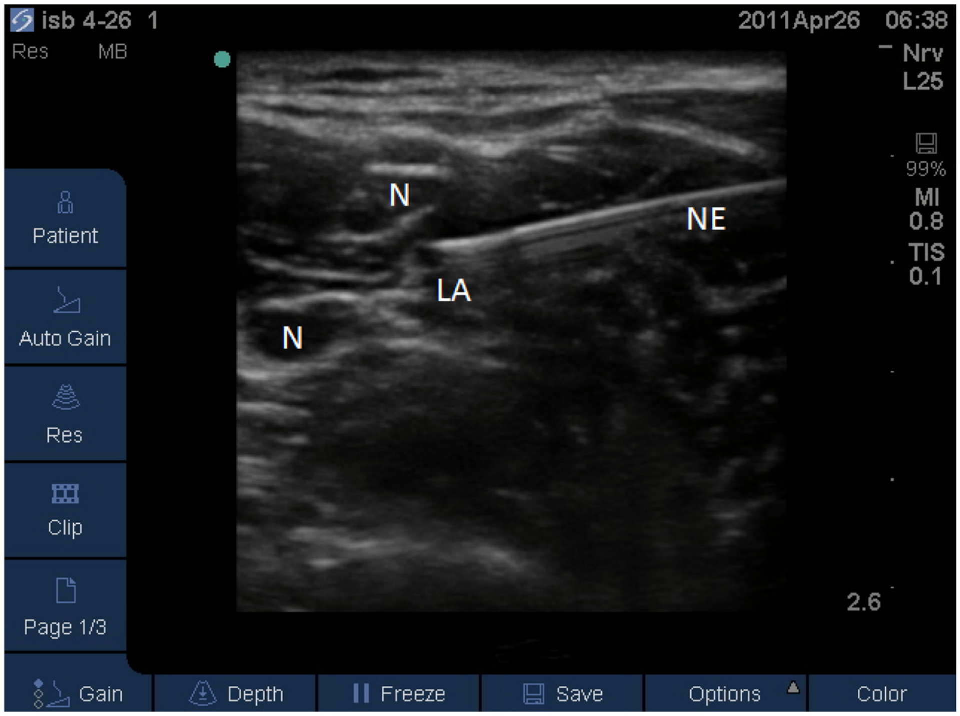


**Figure 2.**
Ultrasound image of interscalene block illustrating incomplete envelopment of nerve roots by local anesthetic solution in the interscalene groove. **In this imaging plane**, the solution is seen to collect only on the lateral side of the roots. (N = nerve root, NE = needle, LA = local anesthetic solution)

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**Table 1**

Demographic variables among groups with complete versus incomplete envelopment of nerve roots in interscalene groove.

| | Complete Envelopment of Nerves | | |
|---|---|---|---|
| **Characteristic** | **No (Group I) n=28 Mean (SD)** | **Yes (Group C) n=22 Mean (SD)** | **p-value** |
| Age | 50 (12.1) | 45.7 19.8 | 0.60 |
| Weight | 187.5 (47.0) | 181.4 (45.5) | 0.77 |
| Height | 69.0 (3.8) | 68.9 (3.8) | 0.87 |
| | % | % | |
| Male | 64.3 | 68.2 | 0.77 |
| Left | 32.1 | 40.9 | 0.52 |

**Table 2**

**Characteristics of Surgical Procedures for Group I and Group C**

| | Incomplete Envelopment Group I (n=28) | Complete Envelopment Group C (n=22) |
|---|---|---|
| Type Surgery: | | |
| RCR | 18 | 13 |
| SAD | 2 | 0 |
| CAPS | 5 | 7 |
| Other | 3 | 2 |
| Side: | | |
| Right | 19 | 13 |
| Left | 9 | 9 |
| Duration (SD) in minutes | 54.9 (15) | 56.5 (17) |

"RCR" represents rotator cuff repair; "SAD" represents subacromial decompression; "CAPS" denotes shoulder joint capsular stabilization or repair; "Other" cases include open reduction-internal fixation of the clavicle, biceps tendon repair, and acromio-clavicular resection.

## Table 3

Clinical block characteristics for Group I and Group C.

| | Group I (N=28) | Group C (N=22) | P |
|---|---|---|---|
| **Stimulation Threshold (in milliamperes)** | **0.38 (0.09)** | **0.52 (0.36)** | **0.91** |
| Block Fully set up at 10min (%) | 43 | 55 | 0.57 |
| Supplementation | 0 | 0 | >.99 |
| Pain in PACU | 2 | 0 | 0.4 |
| Mean Duration(hrs) * | **17.5** | **18** | 0.78 |
| PostOp Neurologic Dysfunction | 0 | 0 | >.99 |

* Patient's report of first experience of pain at surgical site, rounded to the nearest half-hour.