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Comparison of Ultrasound and Nerve Stimulation Techniques for Interscalene Brachial Plexus Block for Shoulder Surgery in a Residency Training Environment: A Randomized, Controlled, Observer-Blinded Trial

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ABSTRACT

Background: The ability to provide adequate intraoperative anesthesia and postoperative analgesia for orthopedic shoulder surgery continues to be a procedural challenge. Anesthesiology training programs constantly balance the time needed for procedural education versus associated costs. The administration of brachial plexus anesthesia can be facilitated through nerve stimulation or by ultrasound guidance. The benefits of using a nerve stimulator include a high incidence of success and less cost when compared to ultrasonography. Recent studies with ultrasonography suggest high success rates and decreased procedural times, but less is known about the comparison of these procedural times in training programs. We conducted a prospective, randomized, observer-blinded study with inexperienced clinical anesthesia (CA) residents—CA-1 to CA-3—to compare differences in these 2 guidance techniques in patients undergoing interscalene brachial plexus block for orthopedic surgery.

Methods: In this study, 41 patients scheduled for orthopedic shoulder surgery were randomly assigned to receive an interscalene brachial plexus block guided by either ultrasound (US group) or nerve stimulation (NS group). Preoperative analgesics and sedatives were controlled in both groups.

Results: The US group required significantly less time to conduct the block (4.3 $\pm$ 1.5 minutes) than the NS group (10 $\pm$ 1.5 minutes), $P = .009$. Moreover, the US group achieved a significantly faster onset of sensory block (US group, 12 $\pm$ 2 minutes; NS group, 19 $\pm$ 2 minutes; $P = .02$) and motor block (US group, 13.5 $\pm$ 2.3 minutes; NS group, 20.2 $\pm$ 2.1 minutes; $P = .03$). Success rates were high for both techniques and were not statistically different (US group, 95%; NS group, 91%). No differences were found in operative times, postoperative pain scores, need for rescue analgesics, or incidences of perioperative or postdischarge side effects.

Conclusion: On the basis of our results with inexperienced residents, we found that using US in guiding the interscalene approach to the brachial plexus significantly shortened the duration of intervals in conduction of the block and onset of anesthesia when compared with NS; moreover, these times could have significant cost savings for the institution. Finally, the use of US technology in an academic medical center facilitates safe, cost-effective, quality care.

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Key Words: Interscalene brachial plexus block, mepivacaine, nerve stimulator equipment, regional anesthetic technique, ropivacaine, ultrasound equipment

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BACKGROUND

Winnie[1] in 1970 popularized the interscalene approach to the brachial plexus. Interscalene brachial plexus block is recommended in the perioperative management of patients presenting for shoulder surgery.[2-6] Benefits of this technique include excellent intraoperative anesthesia and muscle relaxation, better recovery room pain scale scores, and lower incidences of nausea and vomiting; moreover, it may be more cost effective compared to general anesthesia.[7-11] For the past 2 decades, the electrical nerve stimulator has been the gold standard for nerve localization in regional anesthesia.[12-18] However, with recent developments in high-frequency imaging, the use of ultrasound (US) technology has significantly increased for nerve localization.[19-22]

The US-guided technique offers reported additional advantages, including avoidance of intraneuronal/intravascular injection, faster onset times, improved block quality, decreased pain from muscular contractions, prolonged postoperative analgesia, and decreased need for rescue analgesics.[8,21-26]

Teaching regional anesthesia techniques to anesthesiology residents can be demanding. Staff must balance the didactic instruction requirements of the resident against risks of patient discomfort, complications, and increased time requirements to improve block success in the setting of a busy surgical schedule.[27] Proponents of the nerve stimulator technique argue the advantages of this approach based on prior residency training exposure and continued experience in this localization technique.[28,29] Also, the equipment necessary to perform these blocks with nerve stimulation (NS) is a fraction of the cost compared to ultrasonography.[30] Although anesthesiologists experienced in both techniques have reported significant improvements in onset times and success rates of peripheral nerve blocks when using ultrasonography, comparable data for these techniques in training programs are limited.[25,27,28,31] We conducted a prospective, randomized, observer-blinded study with inexperienced clinical anesthesia (CA) residents in years 1 through 3—CA-1 to CA-3—to compare differences in these 2 guidance techniques for patients undergoing interscalene brachial plexus block for orthopedic surgery.

METHODS

After the investigators received approval from the Ochsner Institutional Review Board and obtained written informed consent, 41 patients were enrolled in this prospective, randomized, observer-blinded study. Study subjects were patients of American Society of Anesthesiologists (ASA) physical status I-III who were scheduled to undergo outpatient arthroscopic shoulder surgery with a preoperatively conducted interscalene brachial plexus block. The patients then received either monitored anesthesia care or general anesthesia, based on the preferences of the patient, surgeon, and/or assessment of anesthetic conditions of the block by anesthesiologists not involved with the block. Exclusion criteria included patient refusal, history of peripheral neuropathy, hypersensitivity to local anesthetics, or presence of infection at the injection site. Interscalene brachial plexus blocks were performed by inexperienced CA-1 to CA-3 residents, with a regional anesthesia specialist as the supervising anesthesiologist. All patients were placed in the supine position with the head of the bed elevated 30 degrees, monitored according to ASA guidelines, and premedicated with up to 2 mg of intravenous midazolam and/or up to 100 μg of intravenous fentanyl, titrated to maintain constant verbal communication with the patient. Each patient was then randomly assigned to receive the interscalene brachial plexus block guided by US (US group) or by NS (NS group). Following skin preparation with chlorhexidine antiseptic solution, the interscalene groove was identified by using surface landmarks or ultrasonography, and a skin wheal was created with 1 to 2 mL of 2% lidocaine without epinephrine. After the needle was satisfactorily placed, all patients received a mixture consisting of 20 mL of 1.5% mepivacaine and 20 mL of 0.75% ropivacaine, with 3 μg/mL epinephrine injected in aliquots via a 2-inch regional block needle (Stimuplex, B. Braun, Bethlehem, PA). For both groups, complaints of pain upon injection were minimized using the recommended clinical steps to facilitate proper adjustment of final needle position.[32]

US Group

The lateral neck was examined by using a high-frequency US probe (SonoSite MicroMaxx 3.0 Ultrasound System with L25e/13.6 MHz probe, Bothell, WA), and the roots and trunks of the brachial plexus were identified. A 2-inch, 22-gauge Stimuplex insulated needle (B. Braun Medical) was placed into the interscalene groove via an in-plane approach to enable visualization of the entire needle.[33] In total, 40 mL of the local anesthetic mixture was injected in 5- to 10-mL aliquots, with continuous monitoring for early symptoms or signs of intravenous injection. The needle position was redirected multiple times to improve homogeneity of local anesthetic spread, at the discretion of the attending regional specialist.

NS Group

The stimulating needle (2-inch, 22-gauge Stimuplex insulated needle; B. Braun Medical) was connected to a nerve stimulator (Stimuplex-DIG Stim-300, B. Braun) at an initial current intensity of 1 mA and advanced until it elicited motor responses in the distribution of the axillary, musculocutaneous, ulnar, radial, or median nerves. The current was gradually decreased to a range of 0.3 to 0.4 mA, with a persistent acceptable motor response. In total, 40 mL of the local anesthetic mixture was injected in 5-mL aliquots, with frequent aspirations to assess intravascular needle migration.

Data Collection

Patient demographics included age and ASA physical status classification. After the interscalene block had been conducted, a research assistant who had undergone prior education in assessment of sensory and motor anesthesia and who was unaware of group assignment collected data on each patient. The procedural start time began when the resident performing the block had the Stimuplex needle (NS group) or the US/Stimuplex needle (US group) in hand and ended after the local anesthetic had been administered. Subsequent interval times included

Table 1. Patient Demographics and Types of Orthopedic Procedures

	US Group, Mean ± SD	NS Group, Mean ± SD	*P* Value or Pearson Coefficient
Age, y	59 ± 15	59 ± 11	.89
ASA classification	2 ± 0.5	2 ± 0.4	.3
Surgical procedures			
Acromioplasty	1	1	
Arthroscopy	12	11	
Arthroscopy/ claviculectomy	0	1	
Arthroscopy/rotator cuff repair	3	2	.33
Fracture repair	0	1	
Rotator cuff repair	2	7	
SLAP repair	1	0	

ASA, American Society of Anesthesiologists; SLAP, superior labrum from anterior to posterior tear.

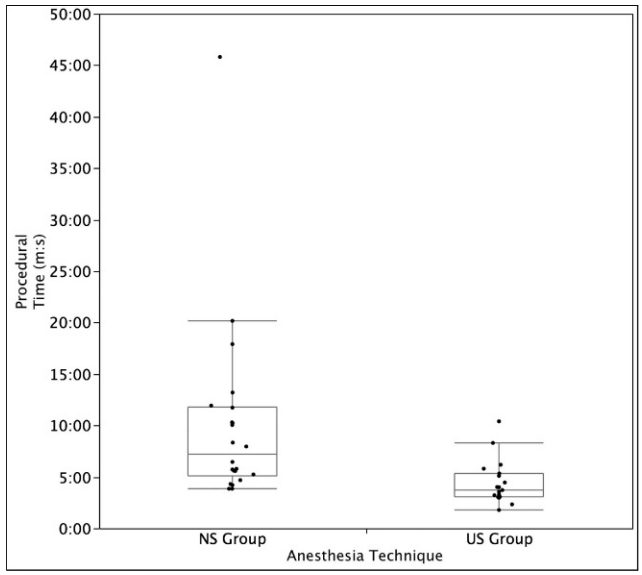

Figure 1. Time interval from needle insertion to removal by anesthesia technique. N = 41 patients; *P* = .009, statistically significant. NS group, nerve stimulation group; US group, ultrasound group.

onset of adequate sensory block in the proposed surgical site, as assessed by progressive loss of sensation to cold and mechanical stimuli, and adequate motor block, as assessed by inability to move the arm. Secondary objectives of this study included success rates, surgical times, postoperative analgesia scores, use of rescue analgesics, incidence of adverse events, and a rank of patient satisfaction at discharge. After a 2-week interval, the research assistant contacted each patient via telephone and documented any onset of delayed paresthesias or sensorimotor deficits. The patient again ranked satisfaction with anesthetic care. Statistical analyses were performed with grouped and paired *t* tests, or χ^2 tests when indicated. Results with a *P* value of less than .05 were considered statistically significant.

RESULTS

The following results were obtained from analysis of 41 patients: 22 patients in the US group and 19 patients in the NS group. Demographic data, including age, ASA classification, and types of surgical procedures, were similar between groups (Table 1). The mean times for completion of the block by residents using both techniques are shown in Figure 1. The procedural times, expressed as mean ± SD, for residents in the NS group were 10 ± 1.5 minutes versus 4.3 ± 1.5 minutes in the US group, $P = .009$ (Figure 1). Following the block, the mean time to achieve adequate sensory block was measured as 19 ± 2 minutes in the NS group and 12 ± 2 minutes in the US group, $P = .02$ (Figure 2A). The mean time to develop adequate motor block was 20.2 ± 2.1 minutes in the NS group and 13.5 ± 2.3 minutes in the US group, $P = .03$ (Figure 2B). The number of complications was similar in both groups and was not statistically significant (Table 2). We observed no hypotension, hypoxemia, hypoventilation, or seizures (Table 3). Block success was high in both groups and not statistically different (US group, 95%; NS group, 91%; $P = .63$). Surgical times, postoperative pain scale scores, and use of rescue analgesics were not statistically different (data not shown). In the follow-up telephone interview conducted by the research coordinator, no significant differences in neurologic complications were observed in this study (Table 4). Satisfaction at discharge and again at 2 weeks was examined, and these data are shown in Figure 3. Satisfaction with either localization technique was high and was not statistically different, $P = .08$ (Figure 3). Finally, both groups had high satisfaction scores when asked if they would undergo the same procedure again (US group, 17 of 19; NS group, 17 of 21; $P = .45$).

DISCUSSION

When residents-in-training performed the interscalene approach to the brachial plexus, we found statistically significant shorter procedural times with the US group than the NS group. A recent review of randomized controlled trials comparing US-guided versus NS-guided techniques[28] observed similar efficacy in the hands of experts. In a retrospective study, Orebaugh and colleagues[27] determined that the use of US with NS required less time to perform

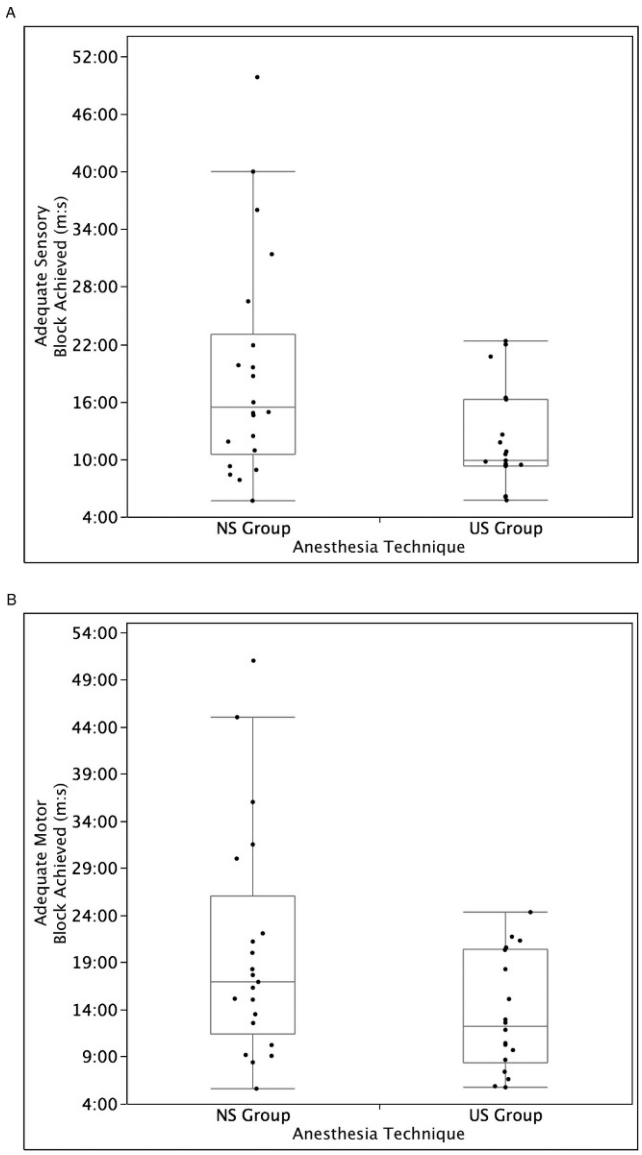

Figure 2A. Time interval to achieve adequate sensory block by anesthesia technique. N = 41 patients; *P* = .02, statistically significant. NS group = nerve stimulation group; US group, ultrasound group. Figure 2B. Time interval to achieve adequate motor block by anesthesia technique. N = 41 patients; *P* = .03, statistically significant. NS group, nerve stimulation group; US group, ultrasound group.

peripheral nerve blocks when compared to use of NS alone. However, to our knowledge, no studies have measured procedural times for both techniques in a prospective, randomized study with inexperienced residents. Williams and colleagues[31] prospectively evaluated ultrasonic guidance versus neurostimulation when conducting supraclavicular blockade. However, only senior residents participated in the study, with 1 procedure requiring staff intervention. In the cited study, US-guided blocks resulted in significant decreases in procedural times (5.0 ± 2.4 minutes) when compared to neurostimulation (9.8 ± 7.5 minutes, $P < .0001$); our results are comparable to those findings in this study. In contrast to the study by Williams and colleagues,[31] our residents were level CA-1 to CA-3 and were relatively inexperienced in either US or NS guidance. Finally, in a large clinical series that studied US or NS,[25] surgical anesthesia was achieved in 99% of patients in the US-guided group and 91% of patients in the NS group ($P < .01$). Sensory block, motor block, and extent of blockade significantly improved in the US group when compared to the NS group. However, staff experienced with either technique conducted this study.[25]

In a novel study, Sites and colleagues[34] evaluated the learning curve of inexperienced residents in a simulated US-guided interventional environment and demonstrated that residents can rapidly learn and improve their speed and accuracy in US-guided simulations. Liu and colleagues[19] measured procedural times in the 2 techniques and found comparable times (5 ± 3 minutes); however, their study included physicians experienced in both techniques. In our study, the use of US significantly decreased the procedural time an average of 5.5 minutes when compared to NS alone. Moreover, further analysis of the data in the US group demonstrated a tighter procedural time range than for the NS group (Figure 1). In the NS group, 8 procedure times exceeded the 95% confidence interval of the US group (Figure 1).

Table 2. Complications During Procedural Block

	US Group	NS Group	Pearson Coefficient
Vascular puncture	0/19	0/22	N/A
Paresthesia	1/18	1/22	.92
Pain upon injection	0/19	2/22	.18
Failed block	1/19	2/22	.64

US, ultrasound; NS, nerve stimulation; N/A, not applicable.

Table 3. Complications Throughout Perioperative Period

	US Group	NS Group	Pearson Coefficient
Hypotension	0/19	0/21	N/A
Hypoxemia	0/19	0/21	
Respiratory rate < 10 breaths/min	0/19	0/21	
Seizure	0/19	0/21	

US, ultrasound; NS, nerve stimulation; N/A, not applicable.

Table 4. Neurologic Complications Reported During Follow-Up Telephone Interview

	US Group	NS Group	Pearson Coefficient
Numbness > 2 wk	1/19	0/21	.29
Radiating pain > 2 wk	4/19	6/21	.58
Motor weakness > 2 wk	2/19	0/21	.13

US, ultrasound; NS, nerve stimulation.

For regional anesthesia to approach the success of general anesthesia, the use of medical tools to reliably or consistently improve peripheral nerve blocks is a necessity.[3,30]

In regard to the faster onset of adequate sensory and motor block in the US group than the NS group, these time differences could be clinically and financially relevant. There is significant financial relevance in the fact that we successfully decreased the time to onset of satisfactory surgical conditions (nonsurgical time) by an average of 11.5 minutes per case; this translates to real cost savings of about $7,700 in reduction of nonsurgical times with a projected annual savings of about $97,000. This projected reduction in nonsurgical time strongly supports the purchase of US equipment for use in residency training programs. Success rates were high and were comparable to cost savings in other studies.[9,25] Differences in reliability of the block and incidence of adverse events were not statistically different. For shoulder surgery, interscalene brachial plexus blocks are commonly conducted to provide surgical anesthesia and superior postoperative analgesia,[3,7,11] but they can have high incidences of postoperative neurologic symptoms.[35-38] In our study, both techniques had similar, low rates of postoperative neurologic complications that were not statistically different between techniques. The etiology of postoperative neurologic complications is unclear,[6,39,40] but fortunately, permanent nerve injury after shoulder surgery is a rare event.[37,38,40,41]

In introducing regional anesthesia to a surgical service, satisfaction of patients and surgeons is a major priority. Surveyed patients prefer general to regional anesthesia and are concerned about needles. Surgeons are concerned about block failures and the increase in nonsurgical times.[5,6,42,43] In this study, we were able to significantly reduce both procedural and onset times. These findings supported the development of a specialized regional rotation at our institution, as well as the associated costs for US technology.

Limitations of the study include the fact that not all institutions have access to US technology in the performance of regional anesthesia. Moreover, the need for facilities and personnel to monitor patients after regional blockade when it is performed in the non–operating room setting is a Joint Commission requirement. However, our analysis of reduction in nonsurgical times lends support to the acquisition of US equipment and monitoring of personnel in teaching institutions. Another limitation of this study was the fact that all anesthesia staff members were proficient in regional anesthetic techniques, so our results may not apply to training programs without a specialized team. However, the benefits of ultrasonography were clearly realized in this setting, and residents should acquire knowledge from experienced clinicians.

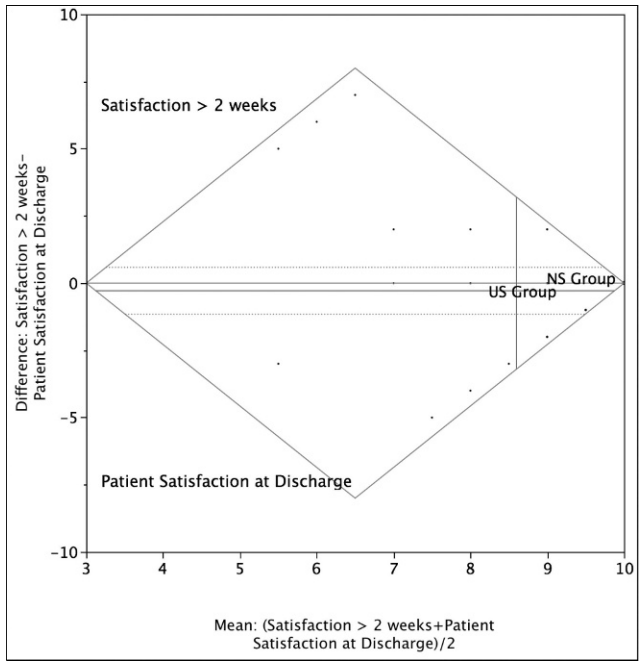

Figure 3. Matched pairs of patient satisfaction scores at discharge and again after 2-week follow-up by anesthesia technique. N = 41 patients; *P* = .08. NS group, nerve stimulation group; US group, ultrasound group.

The novel finding in this study is that in a training program with residents inexperienced in both of the techniques described, the amount of experience and dexterity required to clinically master ultrasonography is not greater than that required for the NS technique. The extrapolation of potential cost savings to the institution is an important finding that could assist healthcare organizations in decreasing costs while still providing safe, cost-effective, quality care.

CONCLUSIONS

We observed that the use of US in the conduction of interscalene brachial plexus block was associated with statistically significant shorter procedural and onset times than NS in a training program. This novel

finding would help training programs support the acquisition of this technology, as our findings lend support to real cost savings for the medical institution. Finally, we achieved high procedural success rates and high patient satisfaction scores, with low post-operative neurologic complications.

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