Comparison of Anterior Suprascapular, Supraclavicular, and Interscalene Nerve Block Approaches for Major Outpatient Arthroscopic Shoulder Surgery

A Randomized, Double-blind, Noninferiority Trial

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ABSTRACT

Background: The interscalene nerve block provides analgesia for shoulder surgery, but is associated with diaphragm paralysis. One solution may be performing brachial plexus blocks more distally. This noninferiority study evaluated analgesia for blocks at the supraclavicular and anterior suprascapular levels, comparing them individually to the interscalene approach.

Methods: One hundred-eighty-nine subjects undergoing arthroscopic shoulder surgery were recruited to this double-blind trial and randomized to interscalene, supraclavicular, or anterior suprascapular block using 15 ml, 0.5% ropivacaine. The primary outcome was numeric rating scale pain scores analyzed using noninferiority testing. The predefined noninferiority margin was one point on the 11-point pain scale. Secondary outcomes included opioid consumption and pulmonary assessments.

Results: All subjects completed the study through the primary outcome analysis. Mean pain after surgery was: interscalene = 1.9 (95% CI, 1.3 to 2.5), supraclavicular = 2.3 (1.7 to 2.9), suprascapular = 2.0 (1.4 to 2.6). The primary outcome, mean pain score difference of supraclavicular–interscalene was 0.4 (–0.4 to 1.2; $P = 0.088$ for noninferiority) and of suprascapular–interscalene was 0.1 (–0.7 to 0.9; $P = 0.012$ for noninferiority). Secondary outcomes showed similar opioid consumption with better preservation of vital capacity in the anterior suprascapular group (90% baseline [$P < 0.001$]) and the supraclavicular group (76% [$P = 0.002$]) when compared to the interscalene group (67%).

Conclusions: The anterior suprascapular block, but not the supraclavicular, provides noninferior analgesia compared to the interscalene approach for major arthroscopic shoulder surgery. Pulmonary function is best preserved with the anterior suprascapular nerve block.

Visual Abstract: An online visual overview is available for this article at http://links.lww.com/ALN/B755. **(ANESTHESIOLOGY 2018; 129:47-57)**

THE interscalene nerve block is a common technique for postoperative analgesia in patients undergoing shoulder surgery. Although tolerated by most patients,[1] an interscalene block is associated with diaphragmatic paresis from phrenic nerve block.[2–4] This adverse effect is particularly concerning in major arthroscopic outpatient shoulder surgery[5] where symptomatic dyspnea from hemidiaphragmatic paralysis is challenging to evaluate and treat. There have been many attempts to mitigate the pulmonary dysfunction[6] associated with regional anesthesia of the brachial plexus.[7–12] One method of avoiding diaphragm paresis is performing blocks more distally along the brachial plexus, and thereby increasing the distance between block location and the phrenic nerve. An example of a block more distal to the interscalene is the supraclavicular block.[13] More recently, Siegenthaler *et al.* have described a proximal ultrasound-guided selective anterior suprascapular nerve block within the supraclavicular fossa.[14] Performing a selective block of the anterior suprascapular nerve may minimize phrenic nerve paresis without

> ### What We Already Know about This Topic
>
> - The interscalene nerve block offers effective analgesia for shoulder surgery
> - Interscalene nerve block frequently causes hemidiaphragmatic paralysis
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> ### What This Article Tells Us That Is New
>
> - This study suggests that anterior suprascapular block provides noninferior analgesia compared to interscalene block, and better preserves vital capacity
> - While supraclavicular block was associated with some vital capacity preservation compared to interscalene block, the analgesia provided by supraclavicular block did not meet noninferiority criteria

compromising analgesia. This anterior suprascapular nerve block, without the addition of an axillary nerve block, has been shown to provide diaphragm-sparing analgesia after total shoulder arthroplasty.[15] These prior results suggest that an anterior suprascapular block alone may be a feasible

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analgesic option for those patients undergoing outpatient shoulder surgery.

The aim of this noninferiority study was to compare the analgesic efficacy of three different brachial plexus nerve block approaches after rotator cuff or Bankart repair of the shoulder. A supraclavicular nerve block and an anterior suprascapular nerve block were separately assessed against the known comparator, the interscalene nerve block. We hypothesized that the supraclavicular block or anterior suprascapular block would provide noninferior analgesia when compared to the interscalene while producing less pulmonary dysfunction. The primary outcome was 11-point numerical rating scale pain scores 60 min after surgery completion. The predetermined noninferiority limit was 1 on the 11-point numerical rating scale. Secondary outcomes, evaluated for superiority, included: opioid consumption, vital capacity measurements, diaphragm excursion, motor and sensory changes of the ipsilateral upper extremity, block- and opioid-related side effects, and patient satisfaction.

Materials and Methods

The Institutional Research Ethics Board (Benaroya Research Institute, Virginia Mason Medical Center, Seattle, Washington) approved this study, which was conducted between November 2014 and November 2016. The study was prospectively registered at clinicaltrials.gov (NCT02287142) by Dr. Auyong (principal investigator) on November 5, 2014. A total of 189 subjects—63 per group—were planned for enrollment in this study. Subjects were screened by a research assistant, research nurse, and the study physicians for eligibility. All subjects with written informed consent were allocated in a 1:1:1 ratio with a computer generated simple randomization by a research assistant to the groups: interscalene, supraclavicular, or suprascapular. Inclusion criteria were: adult (age greater than 18 yr) with American Society of Anesthesiologists (ASA) physical status I to III undergoing unilateral shoulder surgery for rotator cuff or Bankart repair. Exclusion criteria were contraindications to nerve block or local anesthetics, coagulopathy, or chronic opioid use. The follow-up investigators, anesthesia personnel, surgeons, recovery nurses, and the study participants were all blinded to the randomization. All study procedures were completed at the Lindeman Ambulatory Surgery Center, Virginia Mason Medical Center (Seattle, Washington). As all patients were discharged home on the day of surgery, all data collection after discharge to home was collected via telephone by a blinded investigator. The full protocol is available upon request.

Preprocedure Recordings and Measurements

In the preoperative holding area, demographic and baseline data were recorded before any interventions. Pain at rest in the operative shoulder was assessed verbally, recorded on an 11-point numerical rating scale to the tenths of a unit.

Baseline Pulmonary Assessment

Oxygen saturation using pulse oximetry (SpO_2) was recorded on room air. Vital capacity was measured using a Haloscale Standard Respirometer (Mercury Medical, USA). Forced expiratory volume in 1 s (FEV_1) measured with a MicroPlus Spirometer (MD Spiro, USA). Diaphragmatic excursion in centimeters was measured by ultrasound in the mid-axillary line, by finding the zone of apposition between the diaphragm and parietal pleura along the lateral thoracic chest wall using a high-frequency linear ultrasound transducer. The movement of the zone of apposition was measured and marked on the skin during a vital capacity breath.[8,15]

Baseline Motor and Sensory Assessments

Baseline sensation to ice was evaluated over the C4 (top of shoulder), C5 (lateral shoulder), C6 (thumb), C7 (3rd finger), and C8 (4th finger) dermatomes.[16] Biceps contraction and grip strength were assessed via maximum voluntary isometric contraction measurements (MicroFET2; Hoggan Scientific, LLC, USA).

Multimodal Analgesia

As is standard of care for outpatient orthopedic procedures at Virginia Mason Medical Center, all subjects received 975 mg oral acetaminophen and 200 mg oral celecoxib in the preoperative holding area, unless contraindicated.

Nerve Block Procedure

Randomization assignments were kept in sealed envelopes until all preprocedure measurements were complete, and then opened by the research anesthesiologist immediately prior to the nerve block. For the nerve block procedure, subjects were placed in a semirecumbent position with standard ASA monitors and supplemental oxygen. All subjects were sedated with IV propofol (0 to 0.5 mg/kg) and/or IV midazolam (0 to 20 mcg/kg), titrated to a Ramsay Sedation Scale score of 2 to 3. No opioids were given for block placement. For the interscalene nerve block group, a high-frequency linear array ultrasound transducer (SonoSite M-Turbo, USA) was used to identify the cervical nerve roots/trunks as a stacked mono- or bifascicular pattern.[17] A 17-gauge Tuohy needle (Flex-Tip Plus, Arrow International, USA) was then inserted with in-plane technique into the interscalene grove. The interscalene nerve block injection endpoint was posterior to the brachial plexus at this level.[17] For the supraclavicular block group, the brachial plexus was identified in close approximation with the subclavian artery with a high-frequency linear array ultrasound transducer in the supraclavicular fossa. With an in-plane technique, a needle was advanced until reaching the injection endpoint at the superior portion of the brachial plexus, which corresponds to the superior and middle trunks.[17] For the anterior suprascapular nerve block group, the proximal suprascapular nerve was traced laterally as it branched away from the superior trunk or C5 nerve root in the supraclavicular fossa on the anterior

lateral portion of the neck.[14,15] The needle was inserted with the injection endpoint being immediately beneath (caudal) to the suprascapular nerve. The suprascapular nerve is often located underneath the omohyoid muscle at this level.[17] In each group, 15 ml, 0.5% ropivacaine (Naropin; Fresenius Kabi, USA) was injected at the desired location. The duration of a nerve block placement was recorded as the time from needle placement to needle removal. As continuous nerve blocks are a standard of practice at our institution for this procedure, a 19-gauge wire-reinforced catheter (FlexTip Plus) was placed through the Tuohy needle and secured.[18] Catheters were covered with opaque gauze and tape to conceal study randomization. No local anesthetic was infused through the perineural catheters until all data were collected in the postanesthesia care unit (PACU).

Intraoperative Management

General anesthesia was induced with propofol (1 to 2 mg/kg) for the placement of laryngeal mask airway and maintained at less than or equal to 1 minimum alveolar concentration with sevoflurane. If an endotracheal tube placement was required, muscle relaxation was used only for the facilitation of tracheal intubation. A standardized opioid algorithm was used intraoperatively, with IV fentanyl, 25 mcg given for the following criteria: (1) increase in heart rate of 10 beats per minute, or (2) increase in baseline systolic blood pressure of 20 mmHg due to surgical stimulus. Total intraoperative fentanyl use was recorded.

PACU Management

All subjects were brought to the PACU extubated and received by a nurse blinded to randomization.

PACU Recordings and Measurements, 60 Min after Surgery Completion

All PACU recordings and measurements were performed by a blinded researcher, 60 min after the completion of surgery. Patients were deemed ready for PACU discharge when reaching a score greater than or equal to 10 on the 14-point modified Aldrete's scoring system per the blinded PACU nurse.[19]

Postoperative Pain and Opioid Consumption

A standard PACU opioid algorithm was used immediately following surgery: (1) for numerical rating scale pain score 4 to 6, 25 mcg of IV fentanyl was delivered, and (2) for numerical rating scale pain score 7 to 10, 50 mcg of IV fentanyl was delivered. No other analgesics were used during the initial 60 min after surgery. Assessment by the blinded researcher recorded verbal numerical rating scale pain scores in the PACU to the tenths of a unit. Upon completion of assessment by the blinded investigators, both IV and oral opioids were available to the PACU nurse. Oral oxycodone, if necessary, was dosed using the following criteria: (1) numerical rating scale pain score 4 to 6, 5 mg was given, and (2) numerical rating scale

pain score 7 to 10, 10 mg was given. Total PACU opioid consumption was recorded from surgery completion to PACU discharge.

Postoperative Pulmonary and Nerve Block Assessment

All variables, including the primary outcome (pain), were assessed at 60 min after surgery, by a blinded investigator. PACU vital capacity, FEV_1, SpO_2, diaphragmatic excursion, and motor and sensory changes were all measured in the same fashion as the preoperative assessments. Two measurements were recorded for both the pulmonary and motor function outcomes at each time point, with the greater of the two values used in the final analysis.

Adverse Effects

The incidence of opioid-induced adverse events was recorded along with potential brachial plexus block side effects (*e.g.,* Horner syndrome, dyspnea, or hoarseness). Subjects also reported a dichotomous experience of "Satisfied" or "Unsatisfied" with regards to postoperative analgesia.

24-h Follow-up

Telephone calls were placed on postoperative day 1, 24 h after surgery completion, by a blinded investigator. Assessments of verbal numerical rating scale pain scores (rest, average, movement), opioid consumption, opioid-induced and block-related adverse events, patient satisfaction, and perineural catheter complications were recorded.

Statistical Methods

This study was designed to assess the noninferiority of pain in supraclavicular block and anterior suprascapular nerve block cohorts, compared to a common interscalene nerve block group of subjects undergoing major outpatient arthroscopic shoulder surgery. Other studies have determined that a pain score difference of close to 1-point on an 11-point numerical rating scale pain scale (0 to 10) is clinically meaningful in lower-pain surgeries, so the noninferiority margin for the difference in pain was set to 1 point.[20,21]

Institutional pilot data in similar subjects suggested that the SD of PACU pain scores was approximately 1.8. Using these estimates and accounting for a design comparing two cohorts to a common control, we calculated that 60 subjects per group would provide approximately 90% power to demonstrate pain scores with supraclavicular block and anterior suprascapular nerve block exceed those of interscalene nerve block by no more than 1 point. Three additional subjects per group were recruited to account for subject loss prior to follow-up.

The primary endpoint of this trial was pain in PACU. Least-square means were calculated for each group using one-way ANOVA, and the 95% CIs for the pairwise differences in pain were adjusted for multiple comparisons within the ANOVA model. The noninferiority hypothesis (primary endpoint) was tested using a one-sided *t* test for independent

groups (null hypothesis that the difference in pain was greater than or equal to 1 point *vs.* the alternative hypothesis that the difference was less than 1 point). *P* values less than 0.013 were considered significant for these one-sided tests.

Secondary endpoints were compared using the *t* test for independent groups. Categorical variables were compared using the chi-square test (when the expected value of every cell was greater than or equal to 5) or Fisher exact test (if at least one cell had an expected value less than 5). All statistical tests, except for the noninferiority comparisons, are two-sided tests. A Bonferroni correction was used to account for two comparisons to a common control group, so $P < 0.025$ was the threshold for significance for two-sided tests. Statistical analyses were performed using SAS version 9.2 (SAS Institute, Inc., USA).

Results

Two-hundred-thirty potential subjects were evaluated for inclusion in this study. Forty-one potential subjects were excluded, due to either preexisting medical conditions (chronic opioid use, lung disease, and local anesthetic allergies), a refusal to participate during recruitment process, or a language barrier that prohibited the obtainment of informed consent (fig. 1). A total of 189 subjects provided written, informed consent to participate in this study and were subsequently randomized under the study protocol. All subjects completed the acute phase assessments, including

the primary outcome, and all but six provided secondary analyses at 24 h postprocedure (fig. 1). The cohorts were well balanced with no clinically important differences in demographic data or preoperative evaluations (table 1). A total of 63 subjects per group were analyzed for the primary outcome. All nerve blocks were placed successfully at the treatment site selected by randomization. Block placement duration in the interscalene nerve block group was 292 ± 91 s. Compared to the interscalene nerve block group, the supraclavicular block group had a mean block duration of 321 ± 155 s ($P = 0.222$), while the anterior suprascapular nerve block group had a block duration of 346 ± 140 s ($P = 0.014$).

Primary Outcome: PACU Pain Score 60 Min after Surgery

The primary outcome of this study, mean current pain in PACU, was 1.9 for interscalene nerve block (95% CI, 1.3 to 2.5), 2.3 for supraclavicular block (95% CI, 1.7 to 2.9), and 2.0 for anterior suprascapular nerve block (95% CI, 1.4 to 2.6). The difference in mean PACU pain scores between the SCB group and the interscalene nerve block group was 0.4 (adjusted 95% CI, –0.4 to 1.2; $P = 0.088$ for noninferiority) on an 11-point scale. The difference in mean numerical rating scale pain scores between the anterior suprascapular nerve block group and the interscalene nerve block group was 0.1 (adjusted 95% CI, –0.7 to 0.9; $P = 0.012$ for noninferiority) on an 11-point scale. The upper limits of the 95% CI for the mean differences, 1.2 (supraclavicular block-interscalene nerve block) and 0.9 (anterior suprascapular
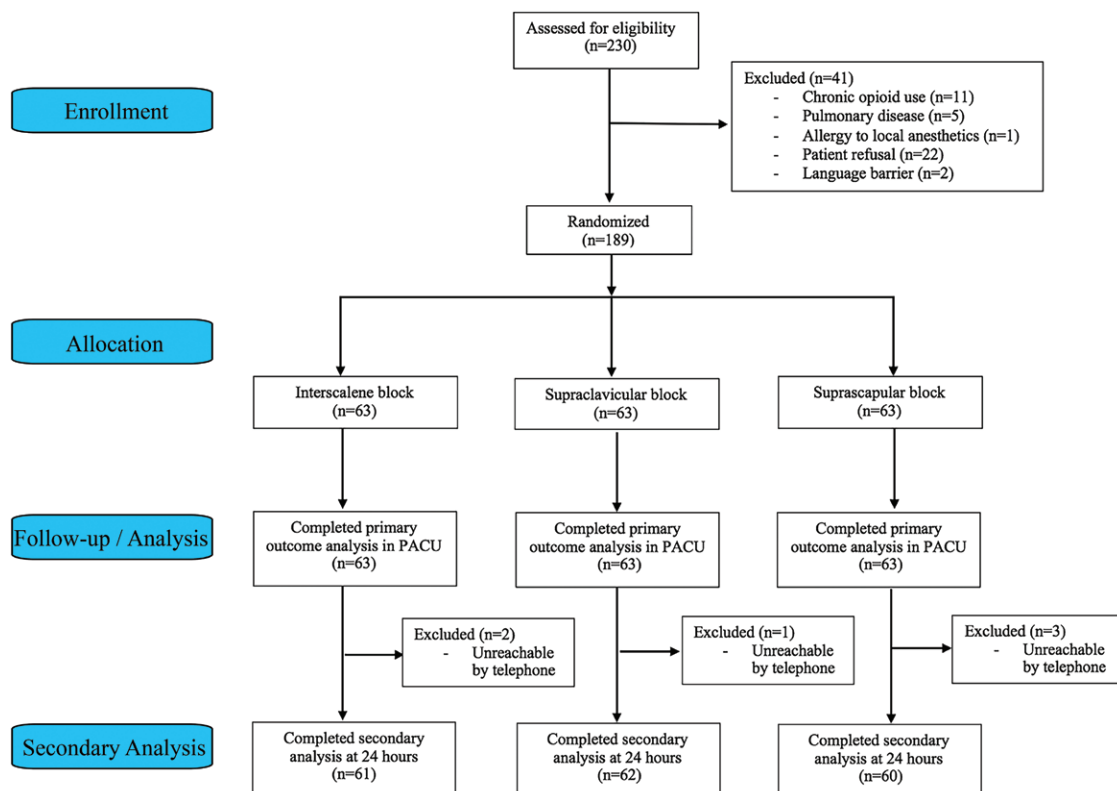

Fig. 1. Consolidated standards of reporting trials statement flow diagram. PACU = postanesthesia care unit.

Table 1. Demographic Data, Preoperative Assessments, Surgical Data

	Interscalene Group (n = 63)	Supraclavicular Group (n = 63)	Suprascapular Group (n = 63)
Demographic data			
Age, yr	54 ± 13	53 ± 14	55 ± 14
Male, n (%)	38 (60%)	39 (62%)	42 (67%)
BMI	27.8 ± 5.6	28.1 ± 4.5	28.9 ± 6.0
ASA I/II/III, n	16/41/6	11/50/2	13/47/3
Preoperative assessment			
Baseline pain (NRS)	2.3 ± 2.2	2.4 ± 2.8	1.6 ± 2.0
Surgical side diaphragmatic excursion, cm	7.8 ± 1.8	7.9 ± 2.1	7.8 ± 2.3
Nonsurgical side diaphragmatic excursion, cm	7.4 ± 1.9	7.1 ± 2.0	7.9 ± 2.2
Vital capacity, l	3.6 ± 1.1	3.6 ± 1.1	3.6 ± 1.0
FEV_1, l	2.8 ± 0.8	2.8 ± 0.8	2.9 ± 0.8
SpO_2	98 ± 2	99 ± 1	98 ± 2
Biceps MVIC, lbs	27 ± 12	27 ± 11	29 ± 15
Grip MVIC, lbs	23 ± 9	23 ± 7	24 ± 8
Surgery			
Type of surgery			
Rotator cuff repair, n (%)	56 (89%)	56 (89%)	59 (94%)
Bankart repair, n (%)	7 (11%)	7 (11%)	4 (6%)
Duration of surgery, min	90 ± 26	88 ± 25	89 ± 22
Multimodal usage, n (%)	42 (67%)	44 (70%)	44 (70%)

Values are shown as mean ± SD or number and %.
ASA = American Society of Anesthesiology classification; BMI = body mass index; FEV_1 = forced expiratory volume in 1s; MVIC = maximum voluntary isometric contraction; NRS = numerical rating scale; SpO_2 = oxygen saturation by pulse oximetry.

nerve block-interscalene nerve block), were both near the prespecified noninferiority margin (Δ = 1). Since the CI for the supraclavicular block-interscalene nerve block difference exceeded 1, only the anterior suprascapular nerve block met the prespecified criteria for noninferiority to the interscalene nerve block based on these results (fig. 2), and the supraclavicular block cannot be considered statistically noninferior. There were no postrandomization exclusions of any subject for the primary outcome due to protocol deviations.

Pain and Opioid Consumption

No differences in PACU pain scores (initial, average, worst) in the first 60 min after surgery were detected when comparing supraclavicular block to interscalene nerve block, or when comparing anterior suprascapular nerve block to interscalene nerve block. Pain was well-controlled at all measured time points. Opioid consumption was clinically similar, and not statistically different, across groups at multiple time intervals, including at the primary outcome assessment (60 min after surgery completion). All other opioid consumption time intervals (intraoperative opioid, total PACU opioid, and 24-h opioid consumption) were similar when comparing supraclavicular block and interscalene nerve block, as well as anterior suprascapular nerve block and interscalene nerve block. (table 2; fig. 3)

PACU Pulmonary Function

Vital capacity preservation in PACU for the supraclavicular block group (76 ± 16%) was superior to the interscalene nerve block group (67 ± 15%; $P = 0.002$), (table 3 and fig. 3). A greater vital capacity preservation was also
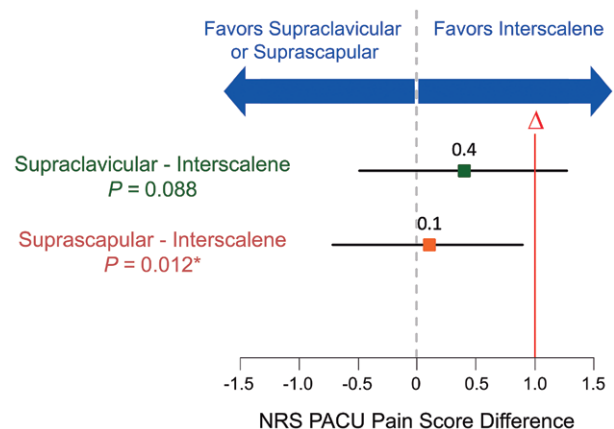

Fig. 2. Noninferiority diagram of numerical rating scale (NRS) pain difference of supraclavicular–interscalene, anterior suprascapular–interscalene. The *solid red line* designates the noninferiority margin (Δ) of 1 on a 0 to 10 pain scale. The *error bars* designate the 95% CI of the difference between the groups. To minimize type I error inflation from multiple comparisons, *P* values less than 0.025 should be considered statistically significant. PACU = postanesthesia care unit.

identified comparing the anterior suprascapular nerve block group (90 ± 15%) to the interscalene nerve block group (67 ± 15%; $P < 0.001$) (table 3 and fig. 3). In absolute numbers, compared to baseline, a mean vital capacity reduction of 1.17 ± 0.68 l was identified in the interscalene nerve block group, which was significantly more than when compared to the supraclavicular block group (0.84 ± 0.55 l; $P = 0.003$). The mean vital capacity reduction in the interscalene nerve

Table 2. PACU Pain and Opioid Consumption—Interscalene, Supraclavicular, and Anterior Suprascapular

	Interscalene Group (n = 63)	Supraclavicular Group (n = 63) [P*]	Suprascapular Group (n = 63) [P*]
Pain			
Initial pain score, PACU arrival, (0–10)	2.0 ± 2.9	2.0 ± 3.2 [P = 0.998]	2.0 ± 3.0 [P = 0.902]
Average postoperative NRS score, 60 min postsurgery, (0–10)	2.1 ± 2.6	2.6 ± 3.1 [P = 0.381]	2.6 ± 2.7 [P = 0.337]
Worst postoperative NRS score, 60 min postsurgery, (0–10)	2.3 ± 2.6	3.1 ± 3.2 [P = 0.134]	3.1 ± 3.0 [P = 0.104]
Opioid consumption			
Intraoperative opioid, fentanyl mcg	36 ± 42	31 ± 38 [P = 0.469]	23 ± 30 [P = 0.041]
Total opioid at primary outcome assessment, 60 min postsurgery, fentanyl mcg	42 ± 50	39 ± 41 [P = 0.772]	35 ± 42 [P = 0.388]
Total PACU opioid, fentanyl mcg	51 ± 85	48 ± 68 [P = 0.826]	52 ± 59 [P = 0.918]

Values are shown as mean ± SD. Total opioid at primary outcome assessment = intraoperative opioid + PACU opioid through 60 min postsurgery. Total PACU opioid = PACU opioid from PACU admission to PACU discharge.

*P value compares each group to interscalene group. To minimize type I error inflation from multiple comparisons, P values less than 0.025 should be considered statistically significant. Significant P value and 95% CI determined using Bonferroni-adjusted alpha level ($\alpha = 0.025$) for individual comparisons. NRS = numerical rating scale; PACU = postanesthesia care unit.
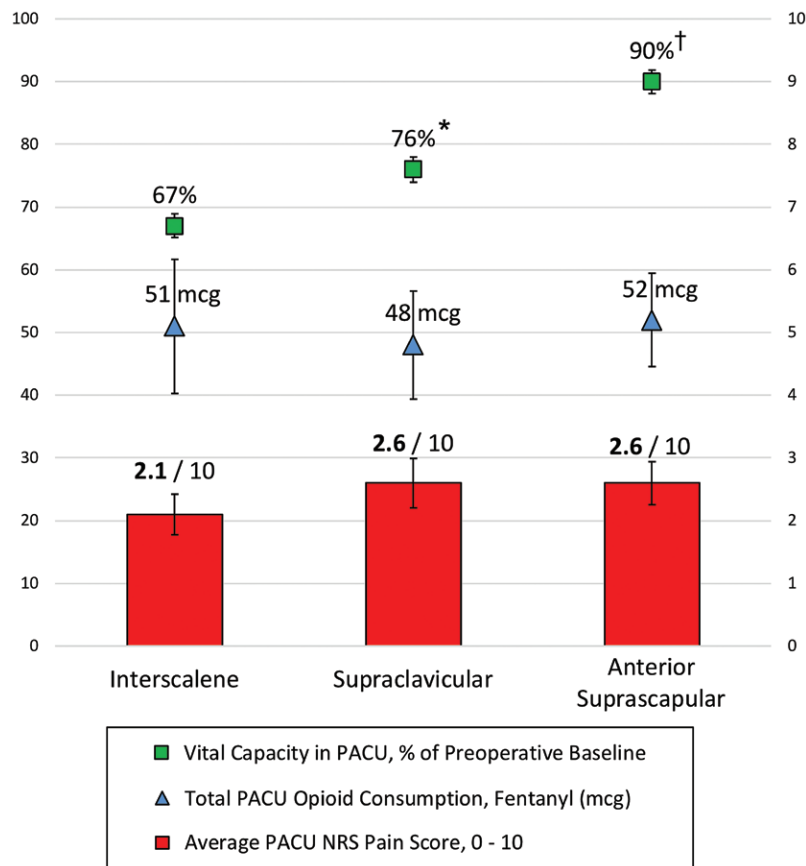

Fig. 3. Clinical outcome differences for interscalene, supraclavicular, and anterior suprascapular nerve block approaches after shoulder surgery. A combined graph of vital capacity, opioid consumption, and pain in the postanesthesia care unit (PACU) for each nerve block approach. Vital capacity is represented as percentage of baseline (*green squares*). Opioid consumption includes all opioids delivered from PACU admission to PACU discharge, in fentanyl equivalents (mcg) (*blue triangles*). Numerical rating scale (NRS) average PACU pain scores (*red bars*). Standard *error bars* are included. *$P < 0.001$ when comparing the interscalene block to the supraclavicular block. †$P < 0.001$ when comparing the interscalene block to the anterior suprascapular block.

block group also exceeded the mean vital capacity reduction found in the anterior suprascapular nerve block group (0.34 ± 0.5 l; $P < 0.001$).

The ipsilateral diaphragmatic excursion was preserved when comparing the supraclavicular block group to the interscalene nerve block group ($P < 0.001$), and when

Table 3. PACU Pulmonary and Nerve Block Outcomes—Interscalene, Supraclavicular, and Anterior Suprascapular

	Interscalene Group (n = 63)	Supraclavicular Group (n = 63) [P*]	Suprascapular Group (n = 63) [P*]
Pulmonary function, 60 min after surgery			
Vital capacity, % of baseline	67 ± 15%	76 ± 16% [P = 0.002*]	90 ± 15% [P < 0.001*]
FEV$_1$, % of baseline	68 ± 13%	74 ± 14% [P = 0.019*]	87 ± 13% [P < 0.001*]
Ipsilateral diaphragmatic excursion reduction, cm	5.9 ± 2.1	3.9 ± 2.8 [P < 0.001*]	1.7 ± 2.4 [P < 0.001*]
Sp$_{O_2}$%, postoperative	96 ± 3	97 ± 2 [P = 0.169]	98 ± 2 [P < 0.001*]
Nerve block outcomes, 60 min after surgery			
Grip strength, % of baseline	27 ± 24%	21 ± 23% [P = 0.163]	34 ± 28% [P = 0.100]
Biceps strength, % of baseline	3 ± 11%	6 ± 17% [P = 0.268]	10 ± 24% [P = 0.025]
Horner syndrome in PACU, n (%)	18 (29)	15 (24%) [P = 0.686]	5 (8%) [P = 0.005*]
Subjective dyspnea in PACU, n (%)	4 (6%)	2 (3%) [P = 0.680]	1 (2%) [P = 0.365]
Hoarseness in PACU, n (%)	14 (22%)	13 (21%) [P > 0.999]	5 (8%) [P = 0.044]
Other			
Satisfaction with analgesia in PACU, n (%)	59 (95%)	60 (97%) [P > 0.999]	61 (97%) [P = 0.680]
Ready for PACU discharge, min	102 ± 35	101 ± 33 [P = 0.903]	98 ± 34 [P = 0.537]

Values are shown as mean ± SD or number and %.
*P value compares each group to interscalene group. To minimize type I error inflation from multiple comparisons, P values < 0.025 should be considered statistically significant. Significant P value and 95% CI determined using Bonferroni-adjusted alpha level (α = 0.025) for individual comparisons.
FEV$_1$ = forced expiratory volume in 1 second; PACU = postanesthesia care unit; Sp$_{O_2}$ = oxygen saturation by pulse oximetry.

comparing the anterior suprascapular nerve block group to interscalene nerve block group (P < 0.001) (table 3). Contralateral diaphragm excursion was similar when comparing the interscalene nerve block group (0.1 ± 2.1 cm) to either the supraclavicular block group (0.0 ± 2.1 cm; P = 0.734), or the anterior suprascapular nerve block group (0.5 ± 1.8 cm; P = 0.213). Oxygen saturation was also significantly higher when comparing the anterior suprascapular nerve block group to the interscalene nerve block group (P < 0.001), but not when comparisons were made between the supraclavicular block group and the interscalene nerve block group (P = 0.169; table 3).

PACU Block Assessment, Side Effects, and Satisfaction

Sensory assessments of the ipsilateral arm revealed no sensory differences when comparing the supraclavicular block group to the interscalene nerve block group. Sensory assessments did reveal statistically significant differences at the C6 (P = 0.014), C7 (P = 0.011), and C8 (P = 0.019) nerve root dermatomes between the anterior suprascapular nerve block and interscalene nerve block groups (fig. 4). Maximum voluntary isometric contraction strength measurements of the biceps and grip strength revealed no statistical differences when comparing either the supraclavicular block group or the anterior suprascapular nerve block group to the interscalene nerve block group. PACU side effects revealed a statistical difference, only in the incidence of Horner syndrome, between the anterior suprascapular nerve block and the interscalene nerve block groups. Subjective dyspnea, hoarseness, satisfaction, and time to readiness for discharge were similar among all groups during PACU assessment (table 3).

24-h Assessment

A total of 183 subjects (61 in interscalene nerve block, 62 in supraclavicular block, and 60 in anterior suprascapular nerve block group) were reached by telephone at 24 h. All continuous catheters remained intact at the 24-h assessment except for one subject (supraclavicular block group), who removed the catheter due to aversion to numbness in the ipsilateral arm and hand. Numerical rating scale pain scores at 24 h (rest, movement, average) were clinically and statistically similar between groups. Total oral opioid consumption (oxycodone equivalents) during the first 24 h after PACU discharge were also similar when comparing the interscalene nerve block group to either the supraclavicular block group or anterior suprascapular nerve block group (table 4). Satisfaction at 24-h assessment was at least 95% for each group, and there was no evidence of group differences. Side effects including dyspnea, hoarseness, and vomiting were similar at this 24-h assessment time point, with the exception of the incidence of Horner syndrome when comparing the anterior suprascapular nerve block group to the interscalene nerve block group (0% vs. 16%; P = 0.001; table 4).

Discussion

This study demonstrates that analgesia assessed by pain scores following major outpatient arthroscopic shoulder surgery in subjects receiving anterior suprascapular nerve blocks alone is noninferior when compared to an interscalene block. Several outcomes evaluating pulmonary function (vital capacity, diaphragm excursion, Sp$_{O_2}$ on room air) did show superiority in the suprascapular group compared to the interscalene group. These data did not demonstrate statistical noninferiority of the supraclavicular block compared to an interscalene block. However, the supraclavicular
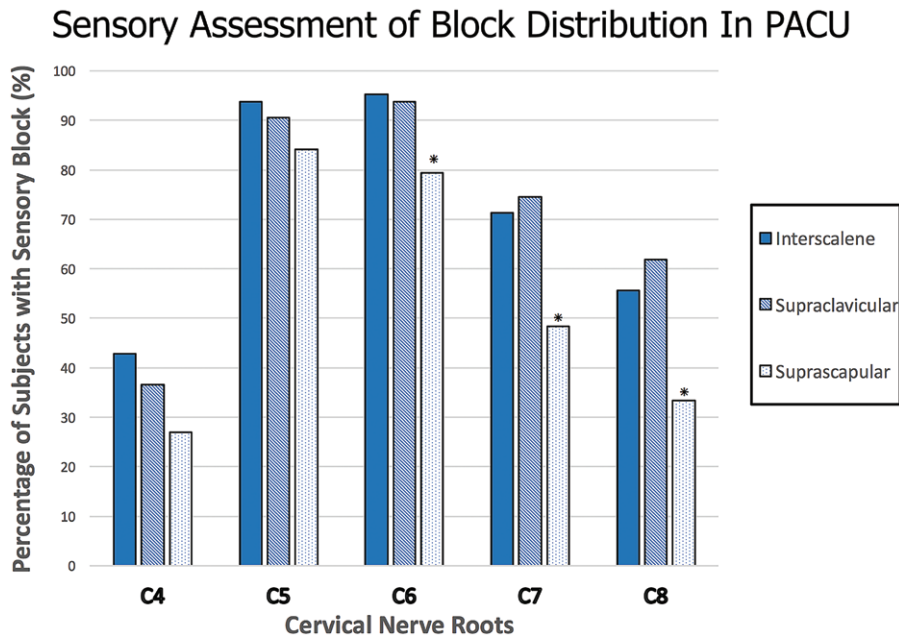
Sensory Assessment of Block Distribution In PACU

Fig. 4. Sensory block determined by sensation to ice, evaluated in the postanesthesia care unit (PACU) 60 min after surgery. To minimize type I error inflation from multiple comparisons, *P* values less than 0.025 should be considered statistically significant (*). Additionally, all comparisons are only between the supraclavicular–interscalene groups or the anterior suprascapular–interscalene groups.

Table 4. 24-h Outcomes—Interscalene, Supraclavicular, Anterior Suprascapular

	Interscalene Group (n = 61)	Supraclavicular Group (n = 62) [P*]	Suprascapular Group (n = 60) [P*]
Analgesic outcomes at 24 h after discharge			
Pain at rest, (NRS 0–10)	1.8±2.1	2.3±2.5 [P = 0.247]	1.4±1.7 [P = 0.323]
Pain with movement, (NRS 0–10)	2.9±2.8	3.5±2.8 [P = 0.248]	2.8±2.4 [P = 0.816]
Average pain since PACU discharge, (NRS 0–10)	1.8±1.8	2.5±2.3 [P = 0.062]	1.9±1.7 [P = 0.744]
Opioid consumption since PACU discharge, oxycodone equivalents (mg)	21±26	20±24 [P = 0.822]	18±19 [P = 0.522]
Block outcomes at 24 h after discharge			
Horner syndrome, n (%)	10 (16%)	3 (5%) [P = 0.044]	0 (0%) [P = 0.001*]
Subjective dyspnea, n (%)	7 (12%)	7 (11%) [P > 0.999]	5 (8%) [P = 0.762]
Hoarseness, n (%)	12 (20%)	12 (19%) [P > 0.999]	8 (13%) [P = 0.464]
Vomiting, n (%)	9 (15%)	5 (8%) [P = 0.270]	2 (3%) [P = 0.054]
Satisfaction with analgesia, n (%)	60 (98%)	59 (95%) [P = 0.619]	59 (98%) [P > 0.999]

Values are shown as mean ± SD.

*P value compares each group to interscalene group. To minimize type I error inflation from multiple comparisons, *P* values less than 0.025 should be considered statistically significant. Significant *P* value and 95% CI determined using Bonferroni-adjusted alpha level (α = 0.025) for individual comparisons.

NRS = numerical rating scale; PACU = Postanesthesia care unit.

group was also associated with improved respiratory outcomes, including a higher preservation of vital capacity and FEV_1, when compared to the interscalene nerve block group.

There are many suggestions in the literature about methods to provide lung-preserving regional anesthesia for shoulder surgery.[7–12] This study provides efficacy data on three variants of brachial plexus nerve blocks for analgesia and pulmonary function. The results suggest several block locations along the brachial plexus provide similar shoulder analgesia, with varying effects on lung function. A recent study examining an ultrasound-guided *distal* suprascapular nerve block reported high failure rates and significantly greater opioid consumption, when compared to an interscalene block.[11] Conversely, our study adds to the sparse literature demonstrating anterior suprascapular nerve block alone, without a concomitant axillary nerve block, results in non-inferior, lung-sparing analgesia when compared to an interscalene nerve block.[15,22]

The innervation of the shoulder is complex,[23,24] however recent advances in anatomical understanding report that the

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posterior division of the upper trunk lies in close approximation to the suprascapular nerve.[25,26] This finding is contrary to prior anatomic descriptions, assuming the anterior division of the upper trunk was closest to the suprascapular nerve. Clinically, these results suggest that local anesthetic delivered *via* a single bolus or continuous catheter at the anterior suprascapular, near its proximal origin along the brachial plexus, is likely to spread to the posterior division of the upper trunk. In turn, this posterior division eventually gives rise to the axillary and subscapular nerves that also contribute to shoulder innervation, making a separate axillary nerve block redundant.[23] This mechanism may explain the comprehensive analgesic efficacy of the anterior approach of suprascapular nerve block, without the addition of a secondary block of the axillary nerve. Although the methods describe targeting the suprascapular nerve block after exiting away from the brachial plexus, we reason part of the efficacy of this approach is due to some spread to other parts of the brachial plexus. Indeed, motor and sensory evaluation at the 60-min PACU assessment revealed some spread of local anesthetic to the brachial plexus from the anterior suprascapular nerve block itself (table 3 and fig. 4). Despite the needle endpoint targeting the suprascapular nerve in isolation, the resulting clinical block routinely includes a partial brachial plexus block.

All assessments in the PACU reflect the pharmacodynamics of the initial ropivacaine bolus. There is a wide range of minimum effective anesthetic volumes of local anesthesia for brachial plexus nerve blocks, but no reported minimum effective anesthetic volumes for suprascapular nerve blocks. The minimum effective anesthetic volumes of local anesthetic ranges from 0.95 ml for interscalene nerve block to 42 ml for supraclavicular block.[27,28] Some of these prior studies were performed with separate injections around the brachial plexus, which further complicate the interpretation of the findings. Additionally, some studies suggest that more local anesthetic is associated with longer block duration when compared to low volume injections.[29,30] The study methods used here—standardizing the local anesthetic to a 15 ml volume—allows for differences between blocks to be interpreted as related to the injection location along the brachial plexus, rather than a variation of local anesthetic volume. Hence, this study used a bolus of 15 ml ropivacaine, 0.5% for all nerve block approaches—a clinically standard dose that allows for both block success and evaluation of adverse effects. One explanation for why the supraclavicular group PACU pain scores did not meet the noninferiority criterion, compared to the interscalene group, is that minimum effective anesthetic volumes studies generally suggest that the supraclavicular block requires a larger volume for block efficacy compared to interscalene nerve block.[27,28] Although not a focus of this study, the cross-sectional surface area of the supraclavicular brachial plexus region may also play a role in the larger minimum effective anesthetic volumes requirements of this approach.[31,32] Additional study is required to

evaluate analgesia and lung function for different local anesthetic volumes placed at these three block locations.

The lack of noninferiority of the supraclavicular brachial plexus approach may also be attributed to the stringent noninferiority margin of 1 on an 11-point numerical rating scale. A larger predetermined margin, or larger sample size, may have led to a statistically significant result; often a 2-point difference on the numerical rating scale is considered clinically significant. However, in comparison to high pain scores, procedures with lower postoperative pain scores (*e.g.*, procedures with nerve blocks) require much smaller changes in numerical rating scale scores to achieve clinical relevance. Although we standardized our study population to invasive arthroscopic shoulder surgery, these procedures are generally associated with relatively low postoperative pain scores in the setting of brachial plexus blocks.[6] This means a small *a priori* defined noninferiority pain margin (less than 1) was required to demonstrate convincingly that pain was not meaningfully worse in the comparison groups. Clinically significant margins of the entire pain spectrum have been determined in previous investigations to be 9 mm to 15 mm on a 100-mm visual analog scale.[33–35]

There are several limitations to this study. First, outcomes *after* the PACU assessments (secondary outcomes) must take into account the use of a continuous infusion of 0.2% ropivacaine. During the initial nerve block preoperatively, the 15 ml local anesthetic was given per protocol, and a continuous catheter was inserted with no infusion started until after all PACU assessments 60 min after surgery completion. The use of a continuous infusion means we have no true pharmacodynamic data of block duration, nor assessment of analgesic efficacy after PACU discharge for a single injection block at these three brachial plexus locations. However, a continuous nerve block was a requirement of our Institutional Review Board, as this is standard of care at our institution for outpatient arthroscopic shoulder surgery. Despite this limitation, these data do suggest efficacy of a continuous nerve block at all three brachial plexus locations, as 24-h opioid use averaged similar oxycodone equivalents. Nevertheless, these analgesic similarities between groups at 24 h should be interpreted with caution, as this effect may be from a combination of both initial block and the continuous catheter infusion. Second, this ultrasound-guided anterior suprascapular approach in the supraclavicular fossa is a relatively novel technique, differing from the more traditional approach performed near the suprascapular notch on the superior margin of the scapula. The results presented here should not be extrapolated to other suprascapular nerve block locations. Third, the preoperative baseline pain scores were lowest in the suprascapular group, although not clinically significant. However unlikely, this could have had an effect on postoperative pain scores. Finally, significant variability exists in the literature about clinical dosing of local anesthetics for upper extremity nerve blocks. Any results

presented here through the primary outcome evaluation at 60 min after surgery reflect the pharmacodynamics of a single injection of 15 ml ropivacaine, 0.5% at the three block locations. Variations of volume or concentration of local anesthetic may have varying effects on analgesia and pulmonary function.

The clinical interpretation of this study primarily depends upon individual patient factors and anticipated outcomes when selecting the appropriate brachial plexus nerve block (fig. 3). This study shows numerical rating scale pain scores were noninferior when comparing an anterior suprascapular and interscalene nerve block. Symptomatic dyspnea did not vary between groups at PACU or 24-h assessments, however, subjects with preexisting lung dysfunction were excluded from this study. Therefore, either the interscalene or suprascapular is indicated when analgesia is the primary goal, as differences in dyspnea were not identified in this healthy patient population. Alternatively, if postoperative lung preservation is a significant priority,[36] then an anterior suprascapular block should be the first to be considered. Respiratory function after the anterior suprascapular approach was clinically, and statistically, superior when compared to the interscalene cohort, which is consistent with the findings of a prior study of these blocks in a total shoulder arthroplasty population.[15] If the anterior suprascapular is unfamiliar, or cannot be visualized,[14] then a supraclavicular approach is a suitable analgesic alternative to potentially lessen pulmonary side effects associated with an interscalene brachial plexus block. Mean block performance times were clinically similar although statistically different, with the biggest difference in block execution being less than 1 min when comparing interscalene to anterior suprascapular. This suggests that performance time should not be a major consideration when choosing a block location along the brachial plexus for shoulder surgery.

In conclusion, this study demonstrates that analgesia provided by an anterior suprascapular nerve block following outpatient arthroscopic shoulder surgery is noninferior to an interscalene nerve block, and best preserves pulmonary function. Additionally, this study also supports the clinical analgesic efficacy of the supraclavicular block, although statistical noninferiority to the interscalene nerve block was not supported by the data.

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Competing Interests

Reproducible Science

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