ANESTHESIOLOGY

Superior Trunk Block Provides Noninferior Analgesia Compared with Interscalene Brachial Plexus Block in Arthroscopic Shoulder Surgery

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EDITOR'S PERSPECTIVE

What We Already Know about This Topic

- Interscalene nerve block is commonly used for shoulder surgery for anesthesia and postoperative analgesia
- Unfortunately, interscalene blocks commonly result in hemidiaphragmatic paralysis

What This Article Tells Us That Is New

- When interscalene block was compared with superior trunk block, less frequent hemidiaphragmatic paralysis was seen in the superior trunk block group
- Superior trunk block was noninferior to interscalene block in terms of pain scores for up to 24 h postoperatively, and superior trunk block patients were no less satisfied

ABSTRACT

Background: Interscalene brachial plexus block of the C5–C6 roots provides highly effective postoperative analgesia after shoulder surgery but usually results in hemidiaphragmatic paresis. Injection around the superior trunk of the brachial plexus is an alternative technique that may reduce this risk. The authors hypothesized that the superior trunk block would provide noninferior postoperative analgesia compared with the interscalene block and reduce hemidiaphragmatic paresis.

Methods: Eighty patients undergoing arthroscopic shoulder surgery were randomized to receive a preoperative injection of 15 ml of 0.5% ropivacaine and 5 μg · ml^{-1} epinephrine around either (1) the C5–C6 nerve roots (interscalene block group) or (2) the superior trunk (superior trunk block group). The primary outcome was pain intensity 24 h after surgery measured on an 11-point numerical rating score; the prespecified noninferiority limit was 1. Diaphragmatic function was assessed using both ultrasonographic measurement of excursion and incentive spirometry by a blinded investigator before and 30 min after block completion.

Results: Seventy-eight patients completed the study. The pain score 24 h postoperatively (means ± SDs) was 1.4 ± 1.0 *versus* 1.2 ± 1.0 in the superior trunk block (n = 38) and interscalene block (n = 40) groups, respectively. The mean difference in pain scores was 0.1 (95% CI, −0.3 to 0.6), and the upper limit of the 95% CI was lower than the prespecified noninferiority limit. Analgesic requirements and all other pain measurements were similar between groups. Hemidiaphragmatic paresis was observed in 97.5% of the interscalene block group *versus* 76.3% of the superior trunk block group (P = 0.006); paresis was complete in 72.5% *versus* 5.3% of the patients, respectively. The decrease in spirometry values from baseline was significantly greater in the interscalene block group.

Conclusions: The superior trunk block provided noninferior analgesia compared with interscalene brachial plexus block for up to 24 h after arthroscopic shoulder surgery and resulted in significantly less hemidiaphragmatic paresis.

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The conventional ultrasound-guided interscalene brachial plexus block involves injection directly around the C5 and C6 nerve roots. Although it provides highly effective postoperative analgesia after arthroscopic shoulder surgery,[1,2] it almost always results in hemidiaphragmatic paresis.[3,4] Other concerns include the risk of intraneural injection into the relatively unprotected roots[5,6] and injury to the dorsal scapular nerve or long thoracic nerve.[7,8] The superior trunk block was described by Burckett-St. Laurent *et al.*[9] as a refinement of the conventional interscalene block technique that addresses these limitations. The superior trunk is formed by the fusion of C5 and C6 nerve roots, and therefore local anesthetic injection around the superior trunk should produce similar analgesia of the shoulder because all the terminal nerves innervating the shoulder arise distal to the superior trunk. Moreover, the site of injection is further away from the phrenic nerve, and this should theoretically reduce the risk of hemidiaphragmatic

This article has been selected for the Anesthesiology CME Program. Learning objectives and disclosure and ordering information can be found in the CME section at the front of this issue. This article is featured in "This Month in Anesthesiology," page 1A. This article is accompanied by an editorial on p. 1207. This article has a visual abstract available in the online version. Part of the work presented in this article has been presented at the 95th Annual Scientific Meeting of the Korean Society of Anesthesiologists in Seoul, Korea, November 8-10, 2018. R.A.K. and J.S.J. contributed equally to this article.

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paresis. However, the analgesic efficacy of the superior trunk block and the associated incidence of hemidiaphragmatic paresis have yet to be systematically investigated in clinical trials. We therefore designed the present randomized, double-blinded, noninferiority clinical trial to test the hypothesis that the superior trunk block would provide noninferior postoperative analgesia to the interscalene brachial plexus block while reducing hemidiaphragmatic paresis in patients undergoing arthroscopic shoulder surgery.

Materials and Methods

Study Participants

After receiving approval by the Samsung Medical Center Research Ethics Board (Seoul, Korea; SMC 2018-02-006-001), this trial was prospectively registered on the Clinical Trial Registry of Korea (Seoul, Korea; KCT0002802 with principal investigator Justin Sangwook Ko) on April 16, 2018. Written informed consent was obtained from all participants. We enrolled 80 adult patients with American Society of Anesthesiologists (ASA) Physical Status classification I to III scheduled for elective unilateral arthroscopic shoulder surgery between April 16, 2018 to September 1, 2018 at Samsung Medical Center, Seoul, Korea. All operations were performed by a single surgeon. Eligible patients were identified from the surgeon's operating list and contacted the day before their surgery to inform them of the study protocol. We excluded patients who refused to participate in the study and those with a history of cardiac, renal, or hepatic disease; preexisting neurologic deficits or neuropathy affecting the brachial plexus; contraindications to peripheral nerve block; preexisting operative respiratory dysfunction; or allergy to local anesthetics. Patients undergoing revision, planned open, or irrigation and debridement procedures were also excluded.

Randomization and Blinding

A member of the Samsung Medical Center who was not otherwise involved in the study performed computer-generated block randomization in a 1:1 ratio to an interscalene brachial plexus block group (n = 40) and a superior trunk block group (n = 40). Allocation of patients to each study group was concealed in an opaque envelope, which was only opened by the block practitioner just before block performance. To eliminate performance bias, all blocks were performed by a single experienced regional anesthesiologist (J.S.K.) together with a single assistant nurse. They were not involved in any other aspect of the conduct of the study. All other research personnel, outcome assessors, and caregivers were blinded to group allocation. Patient blinding was maintained by standardizing the perceptible elements of block performance between both groups: positioning, ultrasound probe placement, needle insertion site, use of neurostimulation, and local anesthetic injection volume.

Brachial Plexus Block Performance

Patients received no premedication before arrival in a dedicated block room, where the brachial plexus block was performed. After applying standard ASA monitoring and supplemental oxygen, IV midazolam (1 to 1.5 mg) was administered for anxiolysis. Before performing the block, a prescan was performed to identify the presence of long thoracic and dorsal scapular nerves and blood vessels around the brachial plexus, using a 6 to 15 MHz high-frequency linear array transducer (X-Porte, Sonosite, USA). The C5 and C6 nerve roots were located within the interscalene groove and traced distally to where they coalesced into the superior trunk. After sterile skin preparation and skin infiltration with 1 ml of 1% lidocaine, an ultrasound-guided interscalene block or superior trunk block was performed according to group allocation using a 22-gauge 50-mm insulated stimulating needle (UniPlex Nanoline, Pajunk, Germany). The interscalene block was performed using the posterior in-plane extraplexus approach.[1] Briefly, the block needle was advanced in-plane to the ultrasound beam at the level of the cricoid cartilage in a lateral-to-medial direction through the middle scalene muscle. The dorsal scapular nerve and long thoracic nerve were identified within the middle scalene muscle and avoided, using a combination of ultrasonographic visualization and neurostimulation with an initial current of 2.0 mA, pulse width of 100 ms, and a frequency of 2 Hz. Once the needle tip was in proximity to the brachial plexus, the current was decreased to 0.5 mA, and a contraction of the biceps or deltoid was sought.[7] The final needle tip position was immediately lateral to the brachial plexus sheath and adjacent to C5 and C6 nerve roots,[10] whereupon 15 ml of 0.5% ropivacaine with 5 $\mu g \cdot ml^{-1}$ epinephrine was injected.

The superior trunk block was performed according to the method described by Burckett-St. Laurent *et al.*[9] The superior trunk was visualized distal to the convergence of the C5 and C6 nerve roots but proximal to the take-off of the suprascapular nerve.[9] The block needle was advanced in-plane to the ultrasound beam in a lateral-to-medial direction under the deep cervical fascia and superficial to the middle scalene muscle, until the needle tip was immediately adjacent to the lateral border of the superior trunk (fig. 1).[11] The same neurostimulation protocol was used to maintain patient blinding, and an identical volume and concentration of local anesthetic was injected.

After block completion, sensory and motor blockade was assessed every 5 min for 30 min. Motor block was evaluated by asking the patient to make a fist and squeeze the assessor's fingers. Motor function was graded on a three-point scale (2 = normal; 1 = weakness; and 0 = complete loss of power). Sensory block was evaluated in the C5 and C6 dermatomes, and the extent of sensory loss was graded on a three-point scale (2 = normal; 1 = loss of sensation to pinprick; and 0 = loss of sensation to light touch). Block success was defined as a sensory score of 0 within 30 min

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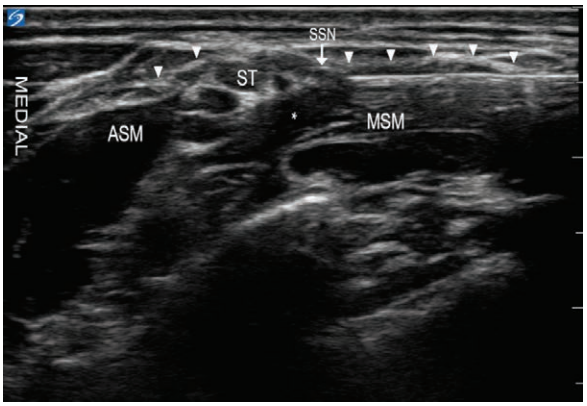

Fig. 1. Ultrasonographic image of the superior trunk block. At the level of the superior trunk, the suprascapular nerve (SSN, *arrow*) is visible in this individual on the lateral side of the superior trunk. The block needle was advanced in-plane in the lateral-to-medial direction until the needle tip was just adjacent to the lateral boarder of the superior trunk. Local anesthetic (*) was injected around the superior trunk. ASM, anterior scalene muscle; MSM, middle scalene muscle; ST, superior trunk. *White down-pointing triangles* indicate the deep cervical fascia.

of local anesthetic injection. The block was also considered a failure if the resting pain score equaled or exceeded the threshold for intense pain, defined as 6 of 10 on an 11-point numerical rating scale (0 = no pain; and 10 = worst pain imaginable), within 3 h after initiation of block.

Assessment of Diaphragmatic Movement and Pulmonary Function

Ipsilateral diaphragmatic excursion was assessed using ultrasound imaging before (baseline) and 30 min after block completion in all patients by a single anesthesiologist (R.A.K.) who was experienced in the technique[12] and who was blinded to group allocation. Diaphragmatic excursion was assessed using M-mode ultrasonography with the patient in the sitting position.[4] A 5 to 2 MHz curvilinear transducer (X-Porte, Sonosite) was placed under the lowest rib at the anterior or midaxillary line, and the liver or spleen was used as an acoustic window. Diaphragmatic excursion between full inspiration and expiration was measured in centimeters. Each test was performed three times, and the values were averaged. The severity of hemidiaphragmatic paresis was measured by the decrease in diaphragmatic excursion (calculated as a percentage difference) between baseline and 30 min after block completion (fig. 2). Complete hemidiaphragmatic paresis was defined as a 75 to 100% decrease or the occurrence of paradoxical movement. Partial and absent hemidiaphragmatic paresis were defined as 25 to 75% decrease and a less than 25% decrease in diaphragmatic excursion, respectively.[13] Overall, we considered hemidiaphragmatic paresis to be present if partial or complete paresis occurred.[12] Pulmonary function was evaluated before and 30 min after block completion using a bedside spirometer (COPd-6, Vitalograph, Ireland) with the patient in the sitting position. The forced expiratory volume at 1 s and forced expiratory volume at 6 s were measured three times, and the values were averaged. We used forced expiratory volume at 6 s as a surrogate for forced vital capacity.[14]

Intraoperative Management

After completion of postblock assessments, all patients underwent general anesthesia with tracheal intubation using IV propofol (1.5 to 2.0 mg · kg^{-1}), rocuronium (0.6 to 0.8 mg · kg^{-1}), and IV remifentanil (0.05 to 0.1 μg · kg^{-1} · min^{-1}). Anesthesia was maintained with sevoflurane in an air–oxygen mixture. A continuous infusion of remifentanil (0.01 to 0.1 μg · kg^{-1} · min^{-1}) was used as needed to maintain the heart rate and mean blood pressure within 20% of preinduction values. No additional intraoperative analgesics were given.

Postoperative Management

After surgery, all patients were transferred to the postanesthesia care unit, where they remained until they met the discharge criteria.[15] Patients were then transferred to the surgical ward for further care. Pain in the shoulder at rest was measured using an 11-point numerical rating scale. Postoperative supplemental analgesia was standardized as follows. At the first report of pain at the surgical site (pain score of higher than 0 of 10), in either the postanesthesia care unit or the surgical ward, IV patient-controlled analgesia (PCA) with fentanyl was initiated by a nurse who was blinded to group allocation. The IV fentanyl PCA pump was programmed to deliver a continuous infusion of 15 μg · h^{-1} and a bolus dose of 15 μg on demand with a lockout interval of 15 min. Both the start time of the IV PCA and cumulative fentanyl dose were recorded automatically by the pump (Gemster, Hospira, Inc., USA), and these data were later downloaded for analysis. Once oral intake was tolerated, all patients received multimodal analgesia consisting of oral acetaminophen 650 mg every 8 h, oral celecoxib 200 mg every 12 h, and oral Targin (oxycodone hydrochloride 10 mg/naloxone hydrochloride 5 mg; Mundipharma, Korea) 1 tablet every 12 h. Patients with persistent pain scores of higher than 4 of 10 despite this regimen received rescue analgesia with either IV morphine 10 mg (if not tolerating oral intake) or oral oxycodone 5 mg. The IV PCA was discontinued on postoperative day 2. All patients remained in the hospital for 3 days after surgery and were followed up at the outpatient clinic on postoperative day 14.

Outcome Measures

The primary outcome was the pain score at rest 24 h postoperatively. Secondary outcomes included resting pain

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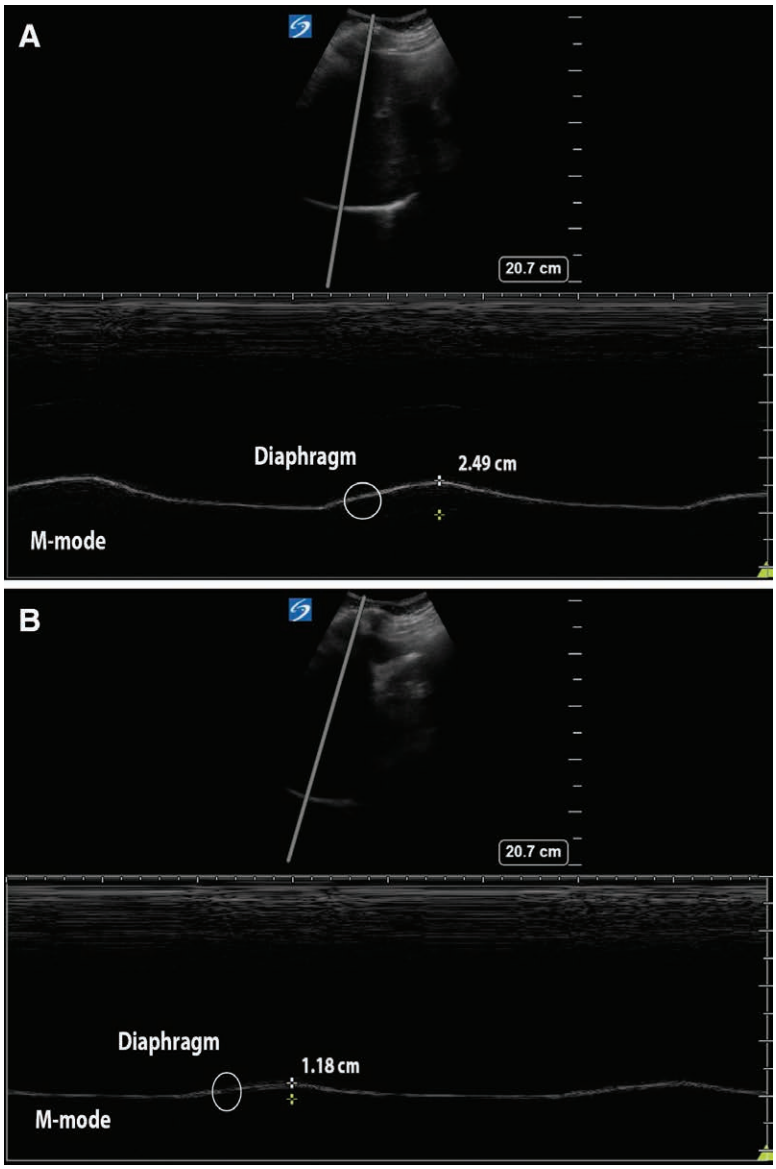

Fig. 2. Curvilinear transducer ultrasound image of the right diaphragm using the liver as an acoustic window in two-dimensional B-mode and M-mode. (*A*) Preblock (baseline) diaphragmatic excursion was checked on deep breathing in M-mode (2.49 cm). (*B*) Postblock assessment of diaphragmatic excursion. Reduced diaphragmatic excursion was seen in M-mode (1.18 cm); the decrease in diaphragmatic excursion was 52.6%, indicating partial hemidiaphragmatic paresis.

scores at 6, 12, and 18 h, area under the 24-h pain curve, maximum pain score during the first 24 h, the incidence and severity of hemidiaphragmatic paresis, cumulative postoperative opioid consumption at 24 h postoperatively (reported as IV morphine equivalents[16]), duration of analgesia (time between block completion and initiation of IV PCA) and motor block (time between block completion and return to presurgical hand grip strength), patient satisfaction with analgesia at 24 h, and quality of sleep on the first night. Patient satisfaction at 24 h, and quality of sleep were measured using a Likert scale (1 = very dissatisfied, 2 = dissatisfied, 3 = neutral, 4 = satisfied, and 5 = very satisfied). Residual block-related neurologic symptoms (persistent numbness, paresthesia, or weakness) were also measured at 24 h, 48 h, and 14 days postoperatively. All assessments and data collection were performed by research personnel blinded to group allocation.

Sample Size Considerations

The sample size was calculated based on the primary endpoint according to the noninferiority hypothesis.[17] The predetermined noninferiority limit (δ) was set to 1 point on

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the 11-point visual analogue score scale.[18] Based on a preliminary analysis (unpublished), an SD of 1.48 was assumed for the pain scores distribution. With $\alpha = 0.05$ and power of 90%, 38 patients were required in each group. Assuming a 5% dropout rate, we decided to enroll 40 patients per group. Primary outcome was analyzed according to the noninferiority approach.[19] The noninferiority hypothesis for the primary outcome was tested using the one-sided *t* test (null hypothesis that the difference in pain scores was at least 1 point *vs.* the alternative hypothesis that the difference in pain scores was less than 1 point) under a significance level of 2.5%. The two-sided 95% CI values,[20] the upper limit of which was equivalent to the upper limit of the one-sided 97.5% CI of the mean difference in pain scores by treatment, are presented in relation to the predefined noninferiority limit and null effect.

Statistical Analysis

After confirming the normality of data distribution using the Shapiro–Wilk test, descriptive statistics and other secondary outcome variables were compared using the *t* test or Mann–Whitney test for continuous variables and the chi-square test or Fisher exact test for categorical variables. Continuous variables are presented as means ± SDs with 95% CI or median and interquartile range as appropriate. Categorical variables are presented as numbers and percentages. Two-sided tests were used, except for the one-sided *t* test of noninferiority. Comparison of area under the curve for pain data to assess cumulative or average pain within the first 24 h used linear interpolation between time points. A Bonferroni correction was used for multiple comparisons. Data analysis was performed using SPSS software (version 25.0, SPSS Inc., USA). For all analyses, $P < 0.05$ was taken to indicate significance. The full trial protocol used during this study is available from the corresponding author on request.

Results

From April 16, 2018 to September 1, 2018, 133 patients scheduled for arthroscopic shoulder surgery were assessed for eligibility, and 53 patients who did not meet the inclusion criteria were excluded (fig. 3). All enrolled patients (n = 80)

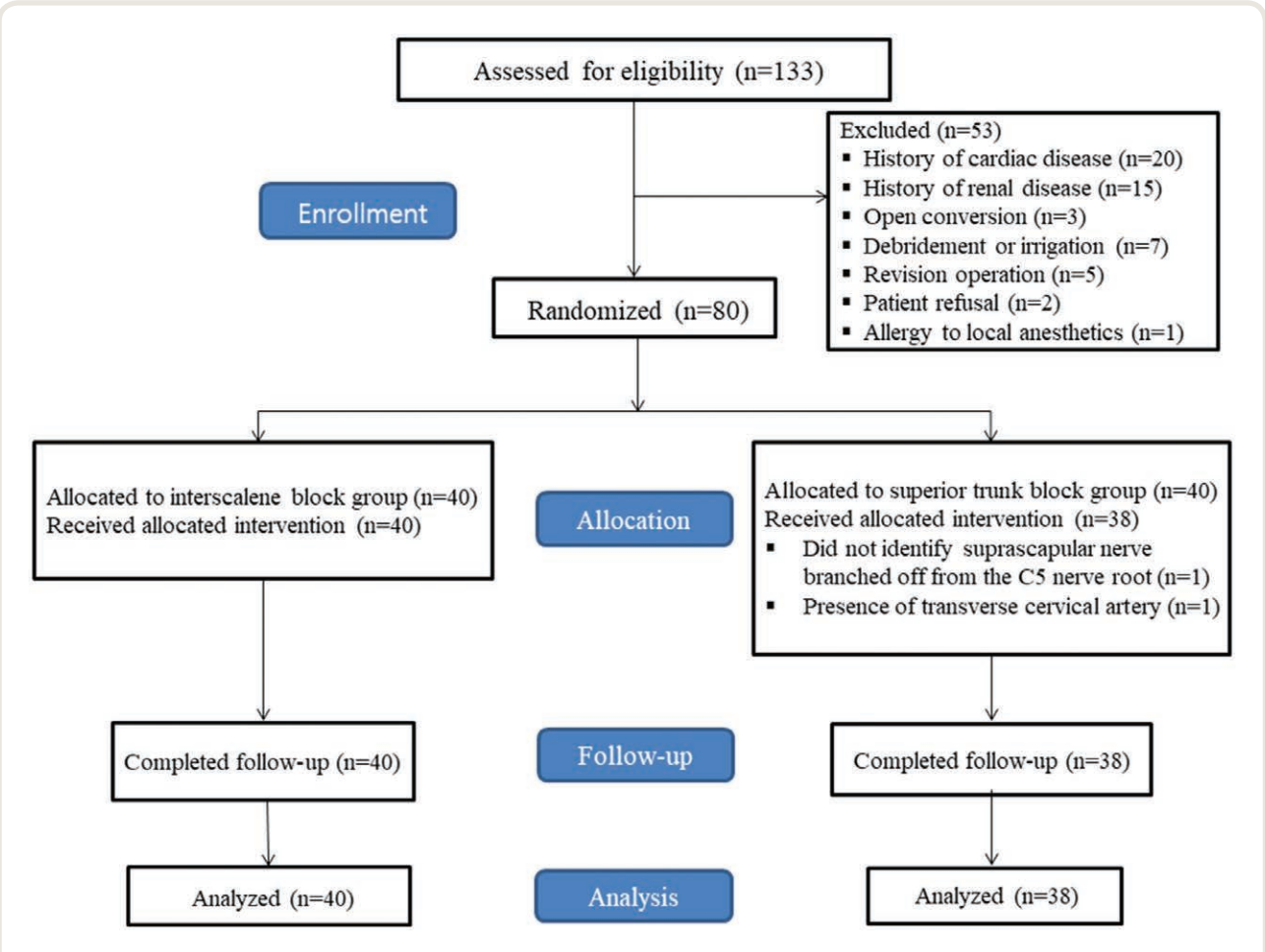

Fig. 3. Consolidated Standards of Reporting Trials flow diagram showing patient progress through the study phases.

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were randomly assigned to one of the two treatment groups (n = 40 each). Two patients allocated to the superior trunk block group were excluded after the preblock ultrasound scan revealed the transverse cervical artery overlying the superior trunk in one patient, and the suprascapular nerve could not be identified branching off from the C5 nerve root in the other patient. Both these patients received interscalene brachial plexus block and did not participate further in the study. A total of 78 patients (interscalene block group [n = 40] and superior trunk block group [n = 38]) completed the study and were included in the final analysis. The baseline patient and surgical characteristics are shown in table 1. All blocks met the criteria for success at 30 min after block completion, and none of the patients required supplemental analgesia or IV PCA initiation in the postanesthesia care unit.

The mean pain score at 24 h postoperatively was 1.4 ± 1.0 in the superior trunk block group (95% CI, 1.0 to 1.7) and 1.2 ± 1.0 in the interscalene block group (95% CI, 0.9 to 1.5). The mean treatment difference (superior trunk block group−interscalene block group) in the pain score at 24 h between the two groups was 0.1 (95% CI, −0.3 to 0.6). Because the upper limit of the 95% CI was lower than the prespecified noninferiority margin (δ = 1), noninferiority was established ($P < 0.001$; fig. 4). There was no significant difference in the 24-h area under the curve for pain scores between the two groups (superior trunk block group *vs.* interscalene block group; 2.1 ± 1.0 *vs.* 2.1 ± 1.1; $P = 0.963$). Pain scores at each time point 6, 12, 18, or 24 h postoperatively were also similar between both groups ($P > 0.522$; fig. 5). There was no significant difference in the reported maximum pain score during the first 24 h postoperatively (superior trunk block group *vs.* interscalene block group; 4.7 ± 1.9 *vs.* 4.8 ± 1.8; $P = 0.361$). Duration of analgesia, duration of motor block, incidence of need for rescue analgesics, and cumulative opioid consumption at 24 h were similar between both groups (table 2). There were no significant differences between groups in the quality of sleep on the first postoperative night or satisfaction with analgesia at 24 h (table 2).

Baseline diaphragmatic excursion on deep breathing was similar in both groups before block performance (table 3). At 30 min after block completion, the mean reduction in diaphragmatic excursion was significantly less in the superior trunk block group compared with interscalene block group (42.2 ± 21.9% *vs.* 79.5 ± 21.1%, $P < 0.001$). The incidence of complete or partial hemidiaphragmatic paresis was significantly lower in the superior trunk block group than in the interscalene block group (29 [76.3%] *vs.* 39 [97.5%] patients; $P = 0.006$). There were significantly more patients with complete hemidiaphragmatic paresis in the interscalene block group (2 [5.3%] *vs.* 29 [72.5%] patients; $P < 0.001$). Twenty-seven patients (71.1%) in the superior trunk block group and ten patients (25%) in the interscalene block group showed partial hemidiaphragmatic paresis. There was no evidence of hemidiaphragmatic paresis at 30 min after the blockade in nine patients (23.7%) and one patient (2.5%) in the superior trunk block and interscalene block groups, respectively. The superior trunk block group had smaller mean reductions in forced expiratory volume at 1 s and forced expiratory volume at 6 s compared with the interscalene group (table 3).

One patient in each of the treatment groups developed symptomatic dyspnea without desaturation after surgery in the postanesthetic care unit. After reassuring the patients, we assessed the diaphragmatic excursion with ultrasound and obtained chest radiographs to exclude pneumothorax. Both patients had complete hemidiaphragmatic paresis. Their symptoms subsided with administration of oxygen in the sitting position and resolved within 12 h. Two and four patients in the interscalene block group and superior trunk block group, respectively, reported numbness in the distal fingers at 24 h, but this resolved spontaneously within 48 h. Four patients in the interscalene block group reported persistent weakness of hand grip at 24 h that resolved within 48 h. None of the patients in the superior trunk block

Table 1. Patient Characteristics

Parameter	Interscalene Block Group (n = 40)	Superior Trunk Block Group (n = 38)
Age, yr	59 [44–64]	56 [42–62]
Sex, male/female	20/20	23/15
Body mass index, kg · m^{-2}	25.7 ± 3.5	25.5 ± 3.3
ASA status, I/II/III	22/18/0	20/17/1
Duration of surgery, min	81 [70–98]	78 [68–89]
Surgical procedure		
Arthroscopy + rotator cuff repair	28	30
Arthroscopy + Bankart repair	5	3
Arthroscopy + superior labrum from anterior to posterior repair	3	3
Arthroscopy + Latarjet	4	2

The values are means ± SDs, median [interquartile range], or number as appropriate.
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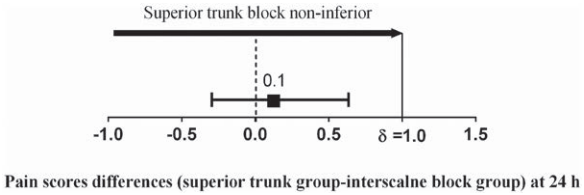

Fig. 4. Noninferiority diagram of numerical rating scale pain score differences in superior trunk block group and interscalene block group at 24 h postoperatively. The *solid line* indicates a noninferiority margin (δ) of 1. *Squares* indicate mean pain score differences, and *error bars* indicate the 95% CIs of the difference between groups. $P < 0.05$ was taken to indicate statistical significance.

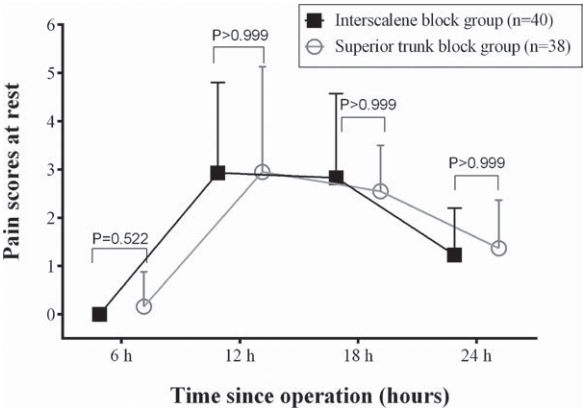

Fig. 5. The numerical rating scale pain scores at rest during the first 24 h after surgery. *Symbols* indicate the means, and *whiskers* indicate SDs. The individual *P* values result from a Bonferroni correction for multiple comparisons. $P < 0.05$ was taken to indicate statistical significance.

group reported motor weakness at 24 h. No other significant adverse events occurred in either group.

Discussion

The ultrasound-guided superior trunk block has only been described in two case reports,[9,21] and this study is the first randomized controlled trial to evaluate the technique in comparison with the conventional ultrasound-guided interscalene brachial plexus block. In this noninferiority clinical trial, we demonstrated that the superior trunk block provided postoperative shoulder analgesia equivalent to that of the interscalene brachial plexus block, as demonstrated by similar pain scores and area under the pain curve up to 24 h postoperatively. In addition, the duration of analgesia and 24-h opioid consumption were similar with both techniques.

It is notable that patients who received a superior trunk block had less deterioration in diaphragmatic excursion and respiratory function compared with interscalene brachial plexus block. The first report on superior trunk block described effective shoulder analgesia without hemidiaphragmatic paresis, and this was attributed to the more distal site of injection.[9] The phrenic nerve and C5 nerve root are anatomically separated by a distance of 1.8 to 2.0 mm in adults at the level of the cricoid cartilage, and the distance between them increases by an additional 3 mm for every centimeter as the phrenic nerve courses more medially into the root of the neck.[22] The likelihood of local anesthetic spread to the phrenic nerve or its origins from the C3–C5 roots is therefore reduced with the superior trunk block, and this hypothesis is supported by our results. Although healthy individuals with transient hemidiaphragmatic paresis are usually asymptomatic,[4] our findings may have important implications for the choice of regional anesthesia technique in patients with compromised respiratory function undergoing shoulder surgery. The incidence of hemidiaphragmatic paresis after conventional interscalene brachial plexus block is as high as 100% with local anesthetic volumes of 20 ml or more.[3,23] Although this incidence can be reduced up to 45% by decreasing local anesthetic volume to 5 to 10 ml,[3,24] this is accompanied by a clinically significant reduction in the duration and potency of perioperative analgesia[25] and may also carry a significant risk of block failure in less-experienced hands. For this reason, it is standard practice in our institution to use 15 ml of 0.5% ropivacaine for interscalene brachial plexus blockade in patients undergoing arthroscopic shoulder surgery.[1,2] This is also consistent with the reported practice in other centers.[26] We believe the significance and generalizability of our findings are strengthened by the use of a pragmatic local anesthetic dose in both treatment groups.

There are other potential advantages of the superior trunk block that we did not formally evaluate in this study. The aim in regional anesthesia of the shoulder is to block the nerves derived from the C5 and C6 nerve roots. The ultrasound-guided interscalene brachial plexus block is therefore generally performed at the level of the cricoid cartilage, where the C5 and C6 roots are located within the groove between the anterior and middle scalene muscles.[9] However, this technique can sometimes be technically challenging. The enveloping fascial layer around the hypoechoic C5 and C6 roots is very thin, which not only makes it difficult to discern the boundaries of the hypoechoic C5 and C6 roots but also increases the risk of subepineurial injection and injury from needle–nerve contact.[6] Anatomical variation in the course of the C5 and C6 roots is common and can further contribute to difficulties with identification. For example, the C5 nerve root may be found within the anterior scalene muscle rather than the interscalene groove,[27] and the C6 nerve root almost always splits into two hypoechoic rootlets that

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Table 2. Postoperative Clinical Parameters between the Interscalene Block Group and Superior Trunk Block Group

Outcomes	Interscalene Block Group (n = 40)	Superior Trunk Block Group (n = 38)	*P* Value*
Duration of analgesia: Time to first pain at surgical site, h	10 ± 3	9 ± 2	0.321
Duration of motor blockade, h	14 ± 4	13 ± 5	0.136
Cumulative opioid consumption at 24 h, mg	60.9 ± 10.2	58.5 ± 9.1	0.281
Patients who received rescue analgesics, n (%)	26 (65)	11 (28.9)	0.488
Quality of sleep on the first night (Likert scale; 1 to 5†)	2 [2–2]	2 [1–2]	0.911
Patient satisfaction with pain relief at 24 h (Likert scale; 1 to 5†)	3 [2–3]	3 [2–3]	0.697
Complications			
Symptomatic dyspnea at postanesthesia care unit/24 h	1/0	1/0	> 0.999
Numbness at fingers at 24 h/48 h/14 days	2/0/0	4/0/0	0.425
Motor weakness at 24 h/48 h/14 days	4/0/0	0/0/0	0.116

The values are means ± SDs, median [interquartile range], or number (percentages) as appropriate.

*The *P* value for the *t* test, Mann–Whitney U test, and Fisher exact test is set at 0.05. †Likert scale where 1 = very dissatisfied, 2 = dissatisfied, 3 = neutral, 4 = satisfied, and 5 = very satisfied.

Table 3. Outcomes of Diaphragmatic Movement and Pulmonary Function between the Interscalene Block Group and Superior Trunk Block Group

Outcomes	Interscalene Block Group (n = 40)	Superior Trunk Block Group (n = 38)	*P* Value*
Incidence of hemidiaphragmatic paresis, n (%)	39 (97.5)	29 (76.3)	0.006
Absent/partial/complete paresis, n	1/10/29	9/27/2	< 0.001
Diaphragmatic excursions, cm			
At baseline	4.1 ± 1.5	4.0 ± 1.3	0.835
At 30 min after blockade	0.8 ± 0.7	2.4 ± 1.1	< 0.001
Decrease in diaphragmatic excursion, %	79.5 ± 21.1	42.2 ± 21.9	< 0.001
Pulmonary function test			
FEV_1 at baseline, l	2.4 ± 0.9	2.2 ± 0.9	0.327
FEV_1 at 30 min after blockade, l	1.3 ± 0.8	1.4 ± 0.9	0.496
Decreases in FEV_1, %	44.7 ± 22.8	33.2 ± 20.5	0.021
Forced expiratory volume at 6 s at baseline, l	2.8 ± 1.0	2.7 ± 1.2	0.570
Forced expiratory volume at 6 s at 30 min after blockade, l	1.7 ± 1.0	2.0 ± 1.1	0.166
Decreases in forced expiratory volume at 6 s, %	41.5 ± 23.0	24.9 ± 16.6	< 0.001

The values are means ± SDs or number (percentages) as appropriate.

*The *P* value for the *t* test and the Fisher exact test is set at 0.05.

FEV_1, forced expiratory volume at 1 s.

can be mistaken for two separate roots (C6 and C7), leading to unintended intraneural injection.[5] However, the C5 root and C6 nerve rootlets inevitably unite to form the superior trunk regardless of the variations in root anatomy proximal to this point, and thus anatomical variation is inconsequential to the superior trunk block.[9,21] In addition, unlike the C5 and C6 roots, the superior trunk is surrounded by a clearly visible and well defined connective sheath. This not only facilitates target visualization and identification but also enhances resilience to needle–nerve contact.[5] Injury to the dorsal scapular nerve and long thoracic nerves is another concern with the posterior in-plane approach to conventional ultrasound-guided interscalene brachial plexus block, because these two nerves run within the middle scalene muscle and thus lie within the needle path.[7,8,28] However, the needle path in superior trunk block does not traverse the middle scalene muscle, instead passing between the deep cervical fascia and middle scalene muscle, thus minimizing the risk of inadvertent needle trauma to these nerves.[9]

There are two points we would like to highlight regarding technical performance of the superior trunk block. First, it is important to perform the block at a level proximal to the take-off of the suprascapular nerve. This can usually be identified as a small hypoechoic circle at the most lateral aspect of the superior trunk, which separates and runs laterally under the omohyoid muscle in the supraclavicular region.[29] In the present study we excluded one patient in the superior trunk block group because we could not confidently identify the suprascapular nerve, which may

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have been due to anatomical variation in the size and location of the suprascapular nerve or the presence of several suprascapular nerves.[29,30] This was mandated by our study protocol; however, it is not a significant issue in clinical practice, because local anesthetic can simply be injected at the point where the C5 and C6 roots coalesce into the superior trunk, which will reliably anesthetize the suprascapular nerve without the need to specifically identify it. Second, the practitioner must be aware that the transverse cervical artery and dorsal scapular artery cross over the brachial plexus and can overlie the superior trunk.[31] The transverse cervical artery and dorsal scapular arteries are usually readily identified by careful observation for pulsatile hypoechoic structures and the use of color Doppler. In the present study, we excluded one patient in the superior trunk block group because of the presence of a transverse cervical artery in the planned needle trajectory. However, in practice, it is usually possible to select a transverse plane for needle advancement that avoids these vessels.

The main limitation of our study was that we defined our primary outcome as the pain score at 24 h postoperatively. On hindsight, this may not reflect the true effect of each technique because the block would, in all probability, have worn off by then. Nevertheless, the other analgesic outcomes, including the 24-h area under the curve for pain, time to first analgesic request, and cumulative opioid requirements, strongly support analgesic equivalence of the superior trunk block and interscalene brachial plexus block. Another limitation is that all blocks were performed by a single experienced anesthesiologist in one center. Although this reduces performance bias and increases study validity, it does limit the generalizability of our findings. Based on our experience as clinicians and educators, however, we believe the superior trunk block is no more difficult to perform than the interscalene brachial plexus block and may in fact be easier for the reasons outlined above. Additional studies would be needed to confirm this. Research is also warranted to determine whether lower volumes of local anesthetic may further decrease the incidence and severity of hemidiaphragmatic paresis with the superior trunk block and whether this has any impact on analgesic effect and duration. Finally, in this study, the superior trunk block was administered for perioperative analgesia and not surgical anesthesia. Although in theory it should work as well as an interscalene block with appropriate local anesthetic dosing, this has yet to be formally proven.

In conclusion, the results of our noninferiority trial demonstrated that the superior trunk block provides similar postoperative shoulder analgesia to conventional interscalene brachial plexus block in patients undergoing arthroscopic shoulder surgery. Moreover, the superior trunk block was superior in preserving diaphragmatic and respiratory function. Based on these findings, the superior trunk block may be considered a viable alternative to the interscalene block, especially in patients at high risk of respiratory complications.

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Competing Interests

The authors declare no competing interests.

Reproducible Science

Full protocol available at: jsko@skku.edu. Raw data available at: jsko@skku.edu.

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References

1. Kang R, Jeong JS, Yoo JC, Lee JH, Choi SJ, Gwak MS, Hahm TS, Huh J, Ko JS: Effective dose of intravenous dexmedetomidine to prolong the analgesic duration of interscalene brachial plexus block: A single-center, prospective, double-blind, randomized controlled trial. Reg Anesth Pain Med 2018; 43:488–95
2. Kang RA, Jeong JS, Yoo JC, Lee JH, Gwak MS, Choi SJ, Hahm TS, Cho HS, Ko JS: Improvement in postoperative pain control by combined use of intravenous dexamethasone with intravenous dexmedetomidine after interscalene brachial plexus block for arthroscopic shoulder surgery: A randomised controlled trial. Eur J Anaesthesiol 2019; 36:360–8
3. Riazi S, Carmichael N, Awad I, Holtby RM, McCartney CJ: Effect of local anaesthetic volume (20 *vs.* 5 ml) on the efficacy and respiratory consequences of ultrasound-guided interscalene brachial plexus block. Br J Anaesth 2008; 101:549–56
4. El-Boghdadly K, Chin KJ, Chan VWS: Phrenic nerve palsy and regional anesthesia for shoulder surgery: Anatomical, physiologic, and clinical considerations. Anesthesiology 2017; 127:173–91
5. Franco CD, Williams JM: Ultrasound-guided interscalene block: Reevaluation of the "stoplight" sign and

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clinical implications. Reg Anesth Pain Med 2016; 41:452–9
6. Orebaugh SL, McFadden K, Skorupan H, Bigeleisen PE: Subepineurial injection in ultrasound-guided interscalene needle tip placement. Reg Anesth Pain Med 2010; 35:450–4
7. Kim YD, Yu JY, Shim J, Heo HJ, Kim H: Risk of encountering dorsal scapular and long thoracic nerves during ultrasound-guided interscalene brachial plexus block with nerve stimulator. Korean J Pain 2016; 29:179–84
8. Thomas SE, Winchester JB, Hickman G, DeBusk E: A confirmed case of injury to the long thoracic nerve following a posterior approach to an interscalene nerve block. Reg Anesth Pain Med 2013; 38:370
9. Burckett-St. Laurent D, Chan V, Chin KJ: Refining the ultrasound-guided interscalene brachial plexus block: The superior trunk approach. Can J Anaesth 2014; 61:1098–102
10. Albrecht E, Bathory I, Fournier N, Jacot-Guillarmod A, Farron A, Brull R: Reduced hemidiaphragmatic paresis with extrafascial compared with conventional intrafascial tip placement for continuous interscalene brachial plexus block: A randomized, controlled, double-blind trial. Br J Anaesth 2017; 118:586–92
11. Neuts A, Stessel B, Wouters PF, Dierickx C, Cools W, Ory JP, Dubois J, Jamaer L, Arijs I, Schoorens D: Selective suprascapular and axillary nerve block versus interscalene plexus block for pain control after arthroscopic shoulder surgery: A noninferiority randomized parallel-controlled clinical trial. Reg Anesth Pain Med 2018; 43:738–44
12. Kang RA, Chung YH, Ko JS, Yang MK, Choi DH: Reduced hemidiaphragmatic paresis with a "corner pocket" technique for supraclavicular brachial plexus block: Single-center, observer-blinded, randomized controlled trial. Reg Anesth Pain Med 2018; 43:720–4
13. Renes SH, Rettig HC, Gielen MJ, Wilder-Smith OH, van Geffen GJ: Ultrasound-guided low-dose interscalene brachial plexus block reduces the incidence of hemidiaphragmatic paresis. Reg Anesth Pain Med 2009; 34:498–502
14. Swanney MP, Jensen RL, Crichton DA, Beckert LE, Cardno LA, Crapo RO: FEV(6) is an acceptable surrogate for FVC in the spirometric diagnosis of airway obstruction and restriction. Am J Respir Crit Care Med 2000; 162:917–9
15. Aldrete JA: The post-anesthesia recovery score revisited. J Clin Anesth 1995; 7:89–91
16. Fishman SM, Ballantyne, Jane C. Rathmell, James P: Opioid analgegics, Bonica's Management of Pain, 4th edition. Philadelphia, Pennsylvania,, Lippincott Williams & Wilkins, 2010, pp. 1172–87
17. D'Agostino RB Sr, Massaro JM, Sullivan LM: Non-inferiority trials: Design concepts and issues: The encounters of academic consultants in statistics. Stat Med 2003; 22:169–86
18. Auyong DB, Hanson NA, Joseph RS, Schmidt BE, Slee AE, Yuan SC: Comparison of anterior suprascapular, supraclavicular, and interscalene nerve block approaches for major outpatient arthroscopic shoulder surgery: A randomized, double-blind, noninferiority trial. Anesthesiology 2018; 129:47–57
19. Piaggio G, Elbourne DR, Altman DG, Pocock SJ, Evans SJ; CONSORT Group: Reporting of noninferiority and equivalence randomized trials: An extension of the CONSORT statement. JAMA 2006; 295:1152–60
20. Walker E, Nowacki AS: Understanding equivalence and noninferiority testing. J Gen Intern Med 2011; 26:192–6
21. Lin JA, Chuang TY, Yao HY, Yang SF, Tai YT: Ultrasound standard of peripheral nerve block for shoulder arthroscopy: A single-penetration double-injection approach targeting the superior trunk and supraclavicular nerve in the lateral decubitus position. Br J Anaesth 2015; 115:932–4
22. Kessler J, Schafhalter-Zoppoth I, Gray AT: An ultrasound study of the phrenic nerve in the posterior cervical triangle: Implications for the interscalene brachial plexus block. Reg Anesth Pain Med 2008; 33:545–50
23. Urmey WF, Talts KH, Sharrock NE: One hundred percent incidence of hemidiaphragmatic paresis associated with interscalene brachial plexus anesthesia as diagnosed by ultrasonography. Anesth Analg 1991; 72:498–503
24. Lee JH, Cho SH, Kim SH, Chae WS, Jin HC, Lee JS, Kim YI: Ropivacaine for ultrasound-guided interscalene block: 5 mL provides similar analgesia but less phrenic nerve paralysis than 10 mL. Can J Anaesth 2011; 58:1001–6
25. Fredrickson MJ, Abeysekera A, White R: Randomized study of the effect of local anesthetic volume and concentration on the duration of peripheral nerve blockade. Reg Anesth Pain Med 2012; 37:495–501
26. Rohrbaugh M, Kentor ML, Orebaugh SL, Williams B: Outcomes of shoulder surgery in the sitting position with interscalene nerve block: A single-center series. Reg Anesth Pain Med 2013; 38:28–33
27. Sakamoto Y: Spatial relationships between the morphologies and innervations of the scalene and anterior vertebral muscles. Ann Anat 2012; 194:381–8
28. Hanson NA, Auyong DB: Systematic ultrasound identification of the dorsal scapular and long thoracic nerves during interscalene block. Reg Anesth Pain Med 2013; 38:54–7
29. Siegenthaler A, Moriggl B, Mlekusch S, Schliessbach J, Haug M, Curatolo M, Eichenberger U:

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Ultrasound-guided suprascapular nerve block, description of a novel supraclavicular approach. Reg Anesth Pain Med 2012; 37:325–8

30. Wiegel M, Moriggl B, Schwarzkopf P, Petroff D, Reske AW: Anterior suprascapular nerve block versus interscalene brachial plexus block for shoulder surgery in the outpatient setting: A randomized controlled patient- and assessor-blinded trial. Reg Anesth Pain Med 2017; 42:310–8
31. Murata H, Sakai A, Hadzic A, Sumikawa K: The presence of transverse cervical and dorsal scapular arteries at three ultrasound probe positions commonly used in supraclavicular brachial plexus blockade. Anesth Analg 2012; 115:470–3

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Dr. E. W. Remsberg's Anesthetic as the "Safest…Brought to Light": Somnoforme

As a 1903 dental graduate of the University of Maryland, Elmer W. Remsberg, D.D.S. (1889 to 1936), had to compete with more established dentists after arriving in Newville, Pennsylvania. Rather than administering "chloroform…cocaine or some other dangerous medium" of anesthetic, Dr. Remsberg advertised his use of "Somnoforme," a volatile French mixture of ethyl chloride, methyl chloride, and ethyl bromide. Touting Somnoforme on his ca. 1907 trade card (*above*) as "the Ideal Anaesthetic," the dentist reminded Newville's citizens that he had "recently installed electric light" and that, day or night, they no longer needed to travel the 11 miles to Carlisle or the 38 miles to Harrisburg for "modern anesthesia." (Copyright © the American Society of Anesthesiologists' Wood Library-Museum of Anesthesiology.)

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