Randomized Controlled Trial

A Comparison of Anesthetic Quality Between Interscalene Block and Superior Trunk Block for Arthroscopic Shoulder Surgery: A Randomized Controlled Trial

Mi Geum Lee, MD, PhD[1], Young Jae Shin, MD[2], Hae Sun You, MD, PhD[2], Choon Hak Lim, MD, PhD[2], Young Jin Chang, MD, PhD[1], and Hyeon Ju Shin, MD, PhD[2]

From: Department of Anesthesiology and Pain Medicine, [1]Gachon University College of Medicine, Gil Medical Center, Incheon, Korea, [2]Korea University College of Medicine, Anam Hospital, Seoul, Korea

Address Correspondence: Hyeon Ju Shin, MD, PhD Department of Anesthesiology and Pain Medicine, Korea University College of Medicine #73 Goryeo-dae-ro, Annam-dong Sungbuk-gu, Seoul, 136-705, Republic of Korea E-mail: may335@naver.com

Disclaimer: There was no external funding in the preparation of this manuscript.

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted manuscript.

Manuscript received: 04-23-2020
Revised manuscript received: 10-19-2020
Accepted for publication: 10-29-2020

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Background: Interscalene block is the most commonly used nerve block for shoulder surgery, and superior trunk block has been investigated as a phrenic-sparing alternative. This randomized controlled trial compared ultrasound-guided interscalene block and superior trunk block as anesthesia for arthroscopic shoulder surgery.

Objectives: Our aims were to determine the superiority of anesthesia quality and compare the risk of hemidiaphragmatic paralysis between these 2 blocks.

Study Design: A randomized, controlled trial.

Setting: Department of Anesthesiology and Pain Medicine, Korea University Anam Hospital.

Methods: Forty-eight patients undergoing elective arthroscopic shoulder surgery under an ultrasound guided brachial plexus block were randomized to receive either an interscalene block (ISB group, n = 24) or a superior trunk block (STB group, n = 24) for surgery. Ten milliliters of 2% lidocaine and 10 mL of 0.75% ropivacaine were used as local anesthesia in both brachial plexus block groups (total 20 mL). In the ISB group, the local anesthesia was injected between the C5–C6 root and at the upper part of C5 with equally divided doses. In the STB group, the local anesthesia was injected into the anterior and posterior parts of the superior trunk with equally divided doses. Sensory blockade of each trocar's insulting site (supraclavicular, axillary, and suprascapular nerve areas) and motor blockade of the axillary nerve (shoulder abduction) and the suprascapular nerve (shoulder external rotation) were assessed by a blinded observer at 5-minute intervals for 30 minutes after the block. Anesthesia quality was assessed using 3 grades (excellent/insufficient/failure). The blinded investigator also assessed the grade of hemidiaphragmatic paralysis (normal/partial/complete) by comparing pre- and postoperative chest radiographs. Primary outcome variables were anesthesia grade and rate of hemidiaphragmatic paralysis. Secondary outcome variables were performance time and anesthesia onset time.

Results: The anesthetic grade was significantly different between the 2 groups (22/2/0 in the ISB group vs. 16/3/5 in the STB group, $P = 0.046$). Both groups displayed equivalent incidence of hemidiaphragmatic paralysis (12/6/6 in the ISB group vs. 7/14/3 in the STB group, $P = 0.063$). No intergroup differences were found in terms of performance time and anesthesia onset time.

Limitations: Our sensory and motor function test was not applied to the subscapular nerve, which serves internal rotation of the humeral head so may be difficult to evaluate in patients with rotator cuff tears. We assessed the diaphragmatic movement by chest radiographs instead of by ultrasound.

Conclusions: The superior trunk block provided lower quality of surgical anesthesia than the interscalene block and did not effectively decrease the risk of hemidiaphragmatic paralysis during arthroscopic shoulder surgery for rotator cuff syndrome.

Key words: Brachial plexus block, hemidiaphragmatic paralysis, interscalene block, superior trunk block, ultrasound

Pain Physician 2021: 24:235-242

Arthroscopic shoulder surgery due to rotator cuff syndrome is associated with significant pain. Symptoms have been effectively managed with interscalene block (ISB), but its benefits have usually been offset by high rates of hemidiaphragmatic paralysis (HDP) via unintentional phrenic nerve blockade (1). This side effect may not be a problem to healthy patients, but it can be very critical in patients with pre-existing pulmonary pathology (2). Paradoxically, these are the very patients who need interscalene blocks, because systemic opioids for pain control will further compromise oxygenation or ventilation (3). Therefore, phrenic-sparing nerve blocks have been a subject of study (3).

Recently, superior trunk block (STB), a refined ultrasound (US)-guided variation of the interscalene block, has been considered as a possible alternative, if it provides as effective surgical anesthesia as the ISB but spares the diaphragm and minimizes adverse effects such as dyspnea and hoarseness (1). Kim et al (1) reported that the STB provides noninferior surgical anesthesia while preserving diaphragmatic function compared to the interscalene block for arthroscopic shoulder surgery, but they didn't measure the anesthetic quality during the progression of the nerve block, just measured the worst pain scores with each block in the post-anesthesia care unit (PACU).

At our institution, arthroscopic shoulder surgery for rotator cuff syndrome has been routinely performed under nerve blocks with only a little sedation, without requiring general anesthesia. By implementing ISB and STB, we could perform a comparison in this study.

Therefore, we aimed to determine the superiority of anesthesia quality and compare the risk of HDP between ISB and STB.

Methods

Study Population

Written informed consent was obtained from all patients after obtaining approval from Korea University's institutional ethics committee (2019AN0500) and registering in the University Hospital Medical Information Network (UMIN) Clinical Trials Registry (UMIN000038865). This study was performed in accordance with the CONSORT 2010 checklist.

Forty-eight patients scheduled for arthroscopic shoulder surgery for rotator cuff syndrome were enrolled in the study. Patients were aged 18 to 80 years and were of American Society of Anesthesiologists (ASA) physical status I or II.

Exclusion criteria included pre-existing neuropathy in the operated limb, ASA ≥ III, coagulation disorders, known allergy to local anesthetics, local infection at the puncture site, chronic obstructive pulmonary disease or respiratory failure, pregnancy, breast-feeding, BMI ≥ 35 kg/m^2, failure to cooperate, and refusal to participate.

We conducted a randomized, controlled, parallel group study (Fig. 1). Written informed consent was obtained the day before surgery. Using a random integer set generator (http://www.random.org/), patients were randomly assigned to one of 2 groups; that is, the interscalene block group (ISB group, n = 24) or the superior trunk block group (the STB group, n = 24), for US-guided brachial plexus block (BPB). The ratio of allocation was 1:1. The researcher not involved in performing the block generated the randomization set and enrolled participants. All procedures were conducted at Anam Hospital, Korea University College of Medicine, Seoul, Korea, from November 2019 to April 2020.

Procedures

All BPBs were performed in the anesthesia procedure room, approximately one hour before the scheduled surgery.

On arrival, supplemental oxygen and standard monitoring (noninvasive blood pressure, electrocardiogram, and pulse oximetry) were applied, and a time-out procedure was performed. Intravenous premedications (fentanyl 50 μg and midazolam 1 mg) were administered to all patients. All blocks were performed by one expert staff anesthesiologist (HJ Shin).

Patients were placed in the lateral decubitus position with the operated shoulder upward and the patient's head slightly raised and facing away from the side to be blocked. The BPBs were performed using US guidance and under strict aseptic conditions. A 22-gauge, 80-mm nerve stimulating needle (Uniplex, Pajunk GmbH Medizintechnologie, Geisingen, Germany) and an ultrasound system (GE LOGIQ P9, GE Healthcare, Little Chalfont, UK) with a high-frequency (L 4 – 12 MHz) linear array transducer were used for the BPB in both groups. The nerve stimulator was used not for the sensory or motor evaluation, but for avoiding injury of the long thoracic nerve and dorsal scapular nerve, which pass through the middle scalene muscle at the level of the interscalene groove (4).

All blocks were performed under local anesthetic infiltration (2 mL of lidocaine 1%). The block needle was inserted in-plane and from a lateral-to-medial direction. The total volume of the local anesthetic (LA) mixture was 20 mL (10 mL of 2% lidocaine mixed with 10 mL of 0.75% ropivacaine) in both groups. LA was injected in 2–3 mL increments, with intermittent aspiration, under real-time

ultrasound visualization of the LA spreading. If paresthesia was elicited during the procedure, the needle was withdrawn by 2–3 mm, and the anesthesiologist ensured no further paresthesia was elicited before injecting the LA. All blocks were performed under one skin puncture. The US screen was kept out of the patient's eyesight.

In the ISB group, the US transducer was applied in sterile fashion on the supraclavicular fossa to find the brachial plexus division lateral to the subclavian artery. Then, the transducer was traced cephalad to the C5–C6 root and interscalene muscles at the level of the cricoid cartilage (1,2). The performer palpated the borders of the trapezius and posterior scalene muscles then localized a point between these muscle bellies where the block needle could be advanced parallel against the US transducer to the C5–C6 root. A skin wheal was raised and the block needle was advanced until its tip was positioned at the interscalene groove (just 1–2 mm lateral to the C5–C6 root). At this point, one-half dose of the LA was injected slowly. The needle was withdrawn 1–1.5 cm and was re-advanced laterally between the upper C5 root and the prevertebral fascia. The remaining one-half dose of LA was then injected slowly (Fig. 2ab).

In the STB group, after finding the needling position in the same way as above, the transducer was moved distally until the superior trunk was first seen. The needle was advanced to the anterior part of the superior trunk, and one-half dose of LA was injected. The needle was withdrawn 1–1.5 cm and re-advanced to the posterior part of the superior trunk, and the remaining one-half dose of LA was injected (Fig. 2cd).

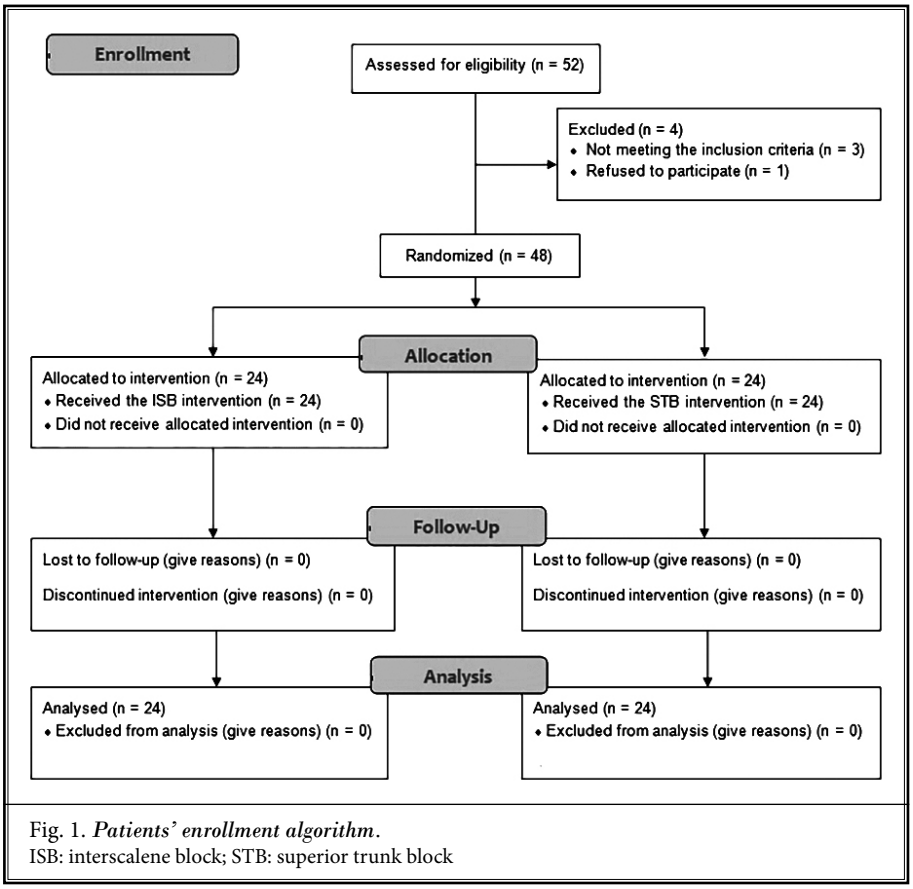

Fig. 1. *Patients' enrollment algorithm.*
ISB: interscalene block; STB: superior trunk block

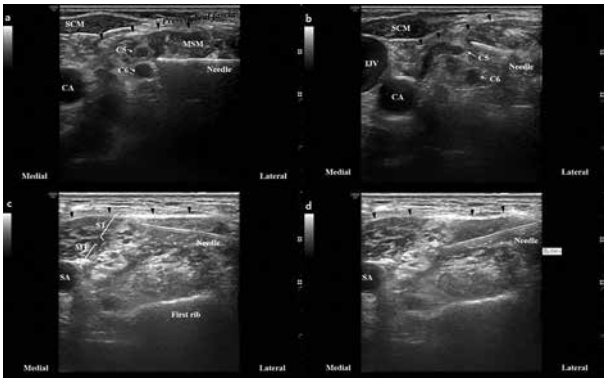

Fig. 2. *Interscalene block vs. superior trunk block methods. In ISB, (a) The block needle is advanced lateral to the C5–C6 root, and one-half dose of LA is injected. (b) The block needle is re-advanced laterally between the upper C5 root and the prevertebral fascia, then the remaining one-half dose of LA is injected. In STB, (c) The block needle is advanced to the anterior part of the superior trunk, and one-half dose of LA is injected. (d) The block needle is re-advanced to the posterior part of the superior trunk, and the remaining one-half dose of LA is injected. Black arrowhead indicates the prevertebral fascia. C5, C5 root; C6, C6 root; CA, carotid artery; IJV, internal jugular vein; SCM, sternocleidomastoid muscle; MSM, middle scalene muscle; ST, superior trunk; MT, middle trunk; SA, subclavian artery.*

Evaluations

Imaging time (the time interval between contact of the ultrasound transducer with the patient and the acquisition of a satisfactory picture) and the needling time (the time interval between the first advancement of the needle through the skin and the end of LA injection, not counting the time of skin wheal placement [1–2 min]) were recorded. Thus, performance time was defined as the sum of imaging and needling times.

A single, blinded observer evaluated the BPB immediately after LA injection, then every 5 minutes for a total of 30 minutes. Sensory block was evaluated using an alcohol swab on each of 4 trocar insertion sites (trocar 1: the cutaneous area overlying the clavicle (supraclavicular nerves); trocar 2: the anterior surface of the deltoid (axillary nerve); trocar 3: the lateral surface of the deltoid (axillary nerve); trocar 4: posterior area (axillary nerve and suprascapular nerve) (Fig. 3) (2). Patients quantified the level of sensory block using an 11-point scale (10 = normal sensation, 0 = no sensation to cold). Complete sensory block was defined as a score of 0 at each site. Motor block was evaluated using shoulder abduction (axillary nerve) and shoulder external rotation (suprascapular nerve) using a 3-point scale, where 2 = no block; 1 = paresis, reduced force compared with the contralateral arm; and 0 = paralysis, inability to overcome gravity (2). Accordingly, complete motor block was defined as a score of 0. Onset time was defined as time required to obtaining full sensory and motor block of each evaluation site. The cases where even one trocar insulting site was missed were excluded from the calculation of the onset time. After completing this evaluation, the patient was moved to the operating room for surgery.

Anesthesia grade was assessed after surgery using a 3-point scale, where excellent = surgery completed with only BPB required; insufficient = surgery completed, but required IV medication (≤ 100 μg fentanyl and ≤ 5 mg midazolam with propofol infusion [25–50 μg/kg/min]) or an additional local injection at the corresponding trocar site; and failure = general anesthesia was required to complete the surgery. When a patient requested sedation during the surgery, precedex 0.5 μg/kg/h was infused based on the decision of the anesthesiologist, who was blinded to the group allocations. The presence of HDP, by comparison of pre- and postoperative chest radiographs, and the presence of other complications (e.g., hematoma formation, pneumothorax, spinal or epidural anesthesia, Horner's syndrome, hoarseness, respiratory distress, neurological complications, nausea, and vomiting) were assessed in the PACU by an independent observer who was blinded to group allocations. HDP grade was assessed as follows: normal = no hemidiaphragmatic paralysis; partial = elevation of the hemidiaphragm ≤ 4 cm above its preoperative position; and complete = elevation of the hemidiaphragm > 4 cm above its preoperative position (5).

Primary outcome variables were anesthesia grade and the occurrence of HDP. Secondary outcome variables were performance time and onset time.

Statistical Analysis

In a preliminary analysis, the case failure rate was one of 10 ISB patients and 3 of 10 STB patients. Forty-eight patients per group were required for an α value of 0.05 and a power of 90%; thus, 48 patients were recruited. Results are presented as mean ± standard deviations, unless otherwise indicated. The statistical analysis was performed using SPSS 19.0 (SPSS, Chicago, IL, USA). The Chi-squared test or the Fisher's exact test was used to analyze categorical data, and the Student's unpaired t-test was used to compare continuous data. Statistical significance was accepted for P values < 0.05.

Results

Patient demographic data are shown in Table 1. All patients underwent arthroscopic shoulder surgery for rotator cuff syndrome. No significant demographic differences were observed between the 2 groups.

Data regarding US-guided BPBs are shown in Table 2.

The anesthesia grade was significantly different in the 2 groups, and the only failed cases were in the STB group. The proportion of patients with complete sensory and motor blocks at each evaluation time up to 30 minutes post-block was similar in both groups (Fig. 4).

The HDP grade was not statistically different between the 2 groups; complete HDP was more common in the ISB group, but partial HDP was more frequent in the STB group. No patients with HDP reported dyspnea; 3 patients with complete HDP (one in the ISB group, and 2 in the STB group) showed SpO^2 < 96%, but this corrected soon after breathing 100% oxygen.

No vascular or pleural punctures occurred during the procedures. Complications included hoarseness (2 cases) in the ISB group, and paresthesia (one case) and hoarseness (3 cases) in the STB group. Complete recovery of sensory and motor function was confirmed in all patients. No neurologic complications were reported during one week of follow-up chart review.

Discussion

First, our findings show that STB did not provide surgical anesthesia equivalent to that of ISB.

The shoulder joint and its adjacent structures derive their sensory innervation from fixed nerves (2).

Cutaneous innervation of the "cape region" overlying the shoulder joint is mediated by the supraclavicular nerves, which originate from the superficial cervical plexus and not the brachial plexus) (3). We did not utilize the superficial cervical plexus separately. However, injection of the upper part of the C5 root in the ISB group (Fig. 2b) and the anterior part of the superior trunk in the STB group (Fig. 2c) appear to cover this area due to the spreading of LA to the prevertebral fascia of the middle scalene muscle.

The anterior shoulder joint is innervated by the subscapular and axillary nerves (both of which originate from the posterior cord) and the lateral pectoral nerve (which originates from the lateral cord). These appear to be nearly covered with brachial plexus block (3).

The posterior shoulder joint is innervated by the suprascapular nerve, which provides 70% of the innervation of the shoulder joint, and small branches of the axillary nerve (1,3,6). The suprascapular nerve is the first major branch of the brachial plexus, separating from the superior trunk (1,4,7). As soon as the C5–C6 roots become the superior trunk, the suprascapular nerve branches off, so inadequate proximal spread of LA can fail to anesthetize the suprascapular nerve (1,2,4,7).

When we performed the STB in this study, we tried to inject LA right where the root becomes trunk, although we could not always block the suprascapular nerve. Kim et al (1) and Burckett-St Laurent et al (4) reported that the STB produced effective surgical anesthesia and perioperative analgesia, and they emphasized targeting the superior trunk just before the suprascapular nerve branches off in their methods. However, we found it difficult to identify the suprascapular nerve by US (Fig. 5), and this may be the determining factor for the anesthetic grade between the 2 groups. In this study, in the insufficient anesthetic grade of the STB group, all additional local injections were performed at the suprascapular nerve region (trocar 4). This could not be avoided in the ISB group also. Even though Fig. 4d fails to show a superior effect of targeting the suprascapular nerve in the ISB group compared to the STB group, all patients with the failed anesthetic grade were in the STB group.

Second, our findings show that STB does not decrease the incidence of HDP compared with ISB.

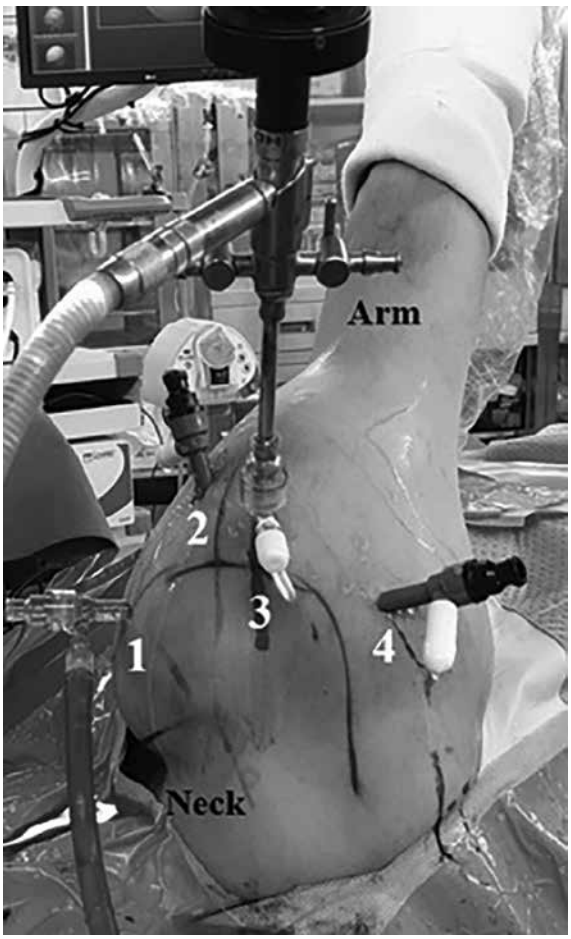

Fig. 3. *External view of the 4 trocar insertion sites. Sensory evaluation sites are matched with 4 trocar insertion sites; trocar 1: the cutaneous area overlying the clavicle (supraclavicular nerves); trocar 2: the anterior surface of the deltoid (axillary nerve); trocar 3: the lateral surface of the deltoid (axillary nerve); trocar 4: posterior area (axillary nerve and suprascapular nerve).*

Table 1. *Patient characteristics in the 2 groups*

	ISB group (n = 24)	STB group (n = 24)	*P* value
Age (yr)	58 ± 14.6	57 ± 11.6	0.711
Gender (M/F)	13 / 11	13 / 11	1
Height (cm)	163.7 ± 8.8	164.8 ± 8.6	0.656
Weight (kg)	66.3 ± 11.2	66.0 ± 11.7	0.076
ASA PS class (I/II)	0 / 24	1 / 23	0.312

Values are means ± standard deviations, or numbers of patients. ISB group: patients that underwent interscalene block; STB group: patients that underwent superior trunk block; ASA PS: American Society of Anesthesiologists physical status.

At the C6 level, the phrenic nerve is situated on the anterior scalene muscle, which is a mere 0.18 cm from the brachial plexus (3), but as the phrenic nerve and the brachial plexus move distally, they start to diverge from each other at a rate of 3 mm/cm (8). Therefore, performing the nerve block further caudally, as in STB, is able to lower the risk of HDP theoretically (2).

Even if the STB is performed, if the LA is spread over the anterior scalene muscle, HDP seems unpreventable. In 2 cases, we identified LA spreading over the anterior scalene muscle during injection of the anterior part of the superior trunk. This was observed through a separation with the prevertebral fascia of the middle scalene muscle on the US view (Fig. 6). Considering the suprascapular nerve, the block was performed at a level proximal to its take-off to enable easy spreading over the anterior scalene muscle. Moreover, the suprascapular nerve could not be identified clearly by separating it from the other superior trunk bundle.

In this study, in cases of complete HDP (6 were in the ISB group, and 3 were in the STB group), no patients reported dyspnea. However, all our patients were in the ASA I and II categories of physical status. Complete HDP could be a problem for patients of ASA level III or greater (especially with pre-existing pulmonary pathology).

Regarding the target of the suprascapular nerve block, we have to inject the LA into the anterior part

Table 2. *Ultrasound-guided ISB vs. STB data*

	ISB group (n = 24)	STB group (n = 24)	*P* value
Op site (Rt./Lt.) (n)	16 / 8	16 / 8	1
Image time (sec)	30.1 ± 16.2	43.5 ± 26.9	0.063
Needling time (min)	2.4 ± 1.2	2.5 ± 0.8	0.880
Performance time (min)	2.9 ± 1.2	3.3 ± 1.0	0.261
Onset time (min)	25.0 ± 4.2	22.1 ± 6.4	0.223
Surgery time (min)	68.1 ± 19.5	73.1 ± 32.8	0.524
Anesthesia grade (n) (excellent/ insufficient/fail)	22 / 2 / 0	16 / 3 / 5	0.046*
Hemidiaphragmatic paralysis (n, %)	12 / 6 / 6	7 / 14 / 3	0.063
(normal/partial/ complete)	50 / 25 / 25	29.2 / 58.3 / 12.5	

Results are expressed as means ± standard deviations, or numbers of patients. ISB group: patients that underwent interscalene block; STB group: patients that underwent superior trunk block. * Statistical significance was accepted for *P* values < 0.05.

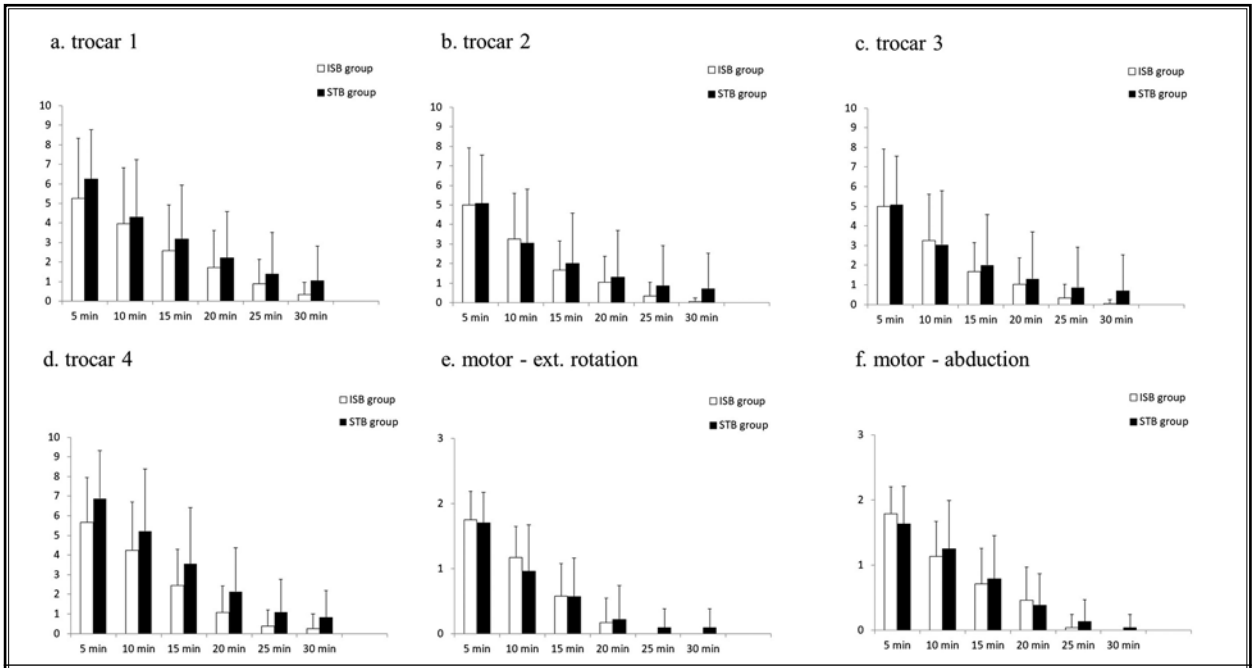

Fig. 4. *Time courses of sensory and motor tests for the 4 trocar insertion sites.*
Vertical axis represents an 11-point scale (10 = normal sensation, 0 = no sensation to cold) (a–d), or a 3-point scale (2 = no block, 1 = paresis, 0 = paralysis) (e,f). Data are presented as means. Bar = standard deviations.

of the superior trunk, and unfortunately, HDP has been known to occur with volumes ≥ 20 mL (1). We believe it is difficult to reduce the volume if we seek adequate anesthesia using BPB only. In the case of this study, we believe that HDP cannot be completely unavoidable in the STB group if we want to achieve a complete level of surgical anesthesia.

Additionally, the incidence of HDP in ISB was lower in our study than in other studies. In a study by Aliste et al (2) (used the same amount of LA [20 mL] as in our study), the incidence of HDP was 100% in ISB. In studies by Kim et al (1) and Kang et al (9) (using 15 mL of LA), the incidences of HDP were 90.5% and 97.5%, respectively, in ISB. However, in our study, the incidence of HDP was only 50% in ISB. Moreover, the incidences of complete HDP were 25% in our study and 73% and 72.5% in studies by Kim et al (1) and Kang et al (9), respectively. The reason for this difference may be that we used the extrafascial injection technique (injecting the LA lateral to the brachial plexus in the middle scalene muscle) instead of the subfascial technique (a conventional technique, injecting the LA at the C5–C6 roots so as to permeate the anterior scalene muscle with LA) for ISB.

This was based on the study of Tran et al (3), the most effective ways to reduce HDP is to use low volume (5 mL), dilute concentrations of LA, and injections 4 mm lateral to the brachial plexus (extrafascial injection) in US-guided block (8). We were unable to reduce the volume or concentration of LA in this BPB-only anesthesia. Therefore, we used the extrafascial injection, and in the ISB group, we advanced the needle just 1–2 mm lateral to the lateral border of the nerve sheath within the body of the middle scalene muscle. This was based on the maximum effective distance required to achieve 95% success in ISBs, according to Albrecht et al (10). We confirmed the LA spreading was within the middle scalene muscle, not over the anterior scalene muscle on US view, but it could not prevent the complete HDP all in ISB group (4). Further studies are needed to determine whether the farther distance to the C5–C6 root can decrease the rate of complete HDP in the ISB group (11). The comparison might be clearer if we repeated the study under the same conditions as the aforementioned study whose results are different from ours (for example, using 15 mL of LA and assessing HDP by US).

Our sensory and motor function test was applied to the axillary and suprascapular nerves, not with the subscapular nerve, which serves internal rotation of the humeral head so may be difficult to evaluate in patients with rotator cuff tears (2).

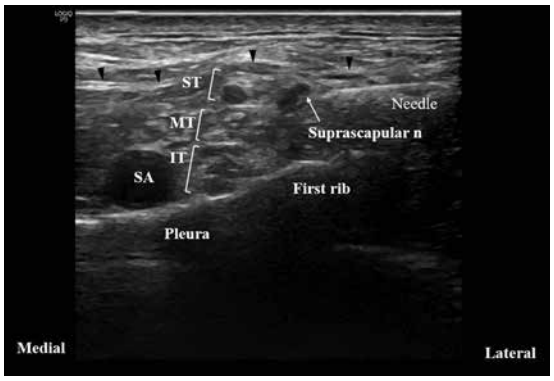

Fig. 5. *Ultrasonography of the suprascapular nerve. When we scan slightly lateral to the superior trunk, the suprascapular nerve is shown branching off the superior trunk. Black arrowhead indicates the prevertebral fascia. SA, subclavian artery; ST, superior trunk; MT, middle trunk; IT, inferior trunk.*

Fig. 6. *Ultrasound image of local anesthetic spreading over the anterior scalene muscle during the superior trunk block (a) The block needle is advanced to the anterior part of the superior trunk. (b) When the LA is injected, prevertebral fascia is separated and the LA penetrates the anterior scalene muscle (ASM) under pressure of injection. (c) After the LA injection, LA is shown around the ASM beneath the prevertebral fascia.*
Black arrowhead indicates the prevertebral fascia. ASM, anterior scalene muscle; MSM, middle scalene muscle; ST, superior trunk; SCM, sternocleidomastoid muscle; * = local anesthetics.

The anesthesiologist who performed all blocks in the present study was not blinded to group allocations. However, the sensory-motor test evaluations were performed by an independent blinded observer. Therefore, we believe that unintentional bias had little impact on the overall results (12).

US-assisted regional anesthesia is affected by many factors such as the US resolution, type of approach, performer's skill, and patients' position. Therefore, we should investigate many procedures performed by different performers in different medical environments.

Certain US approaches could be widely used if the ease of performance was improved to suit ordinary performers without expertise. Although many block techniques have shown promise in sparing the phrenic nerve, none has been a reliable surgical anesthetic alternative to the ISB so far (1,2). Based on our results, even though HDP is still a problem in ISB, the STB does not seem to be a viable alternative to the ISB for anesthesia of the arthroscopic shoulder surgery. Our study did not encompass all aspects of STB for performers. However, it might inform performers about the careful considerations required when implementing STB.

Conclusion

In conclusion, the STB provided lower quality of surgical anesthesia compared to the ISB, and it did not decrease the risk of HDP during arthroscopic shoulder surgery for rotator cuff syndrome.

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