Research Square

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Low-Volume, Low-Concentration Ropivacaine in Superior Trunk Block Versus Interscalene Block for Shoulder Arthroscopy: A Randomized Controlled Trial of Diaphragm-Sparing Analgesia

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Abstract

Background: Interscalene brachial plexus block (ISB) is the gold standard for analgesia in shoulder arthroscopy. However, it causes hemidiaphragmatic paralysis (HDP) in nearly all patients when conventional high-volume regimens are used. The superior trunk block (STB) offers diaphragm-sparing potential; however, its optimal dosing remains undefined, and data on low-volume, low-concentration regimens for both techniques are lacking. This study compared STB and ISB using 8 ml of 0.25% ropivacaine to determine whether this optimized low-volume regimen provided superior diaphragmatic protection without compromising analgesic efficacy.

Methods: This prospective, double-blind, randomized controlled trial enrolled 170 patients who underwent elective arthroscopic shoulder surgery at a single center in China (April 2024 - February 2025). Participants were randomly assigned (1:1) to receive ultrasound-guided STB or ISB with 8 ml 0.25% ropivacaine using a standardized two-point injection technique. The primary outcome was the incidence of HDP (partial or complete) at 30 minand 3 h post-injection, assessed by M-mode ultrasound diaphragmatic excursion. The secondary outcomes included pain scores (numeric rating scale), sensory block duration, grip strength, opioid consumption, and adverse events.

Results: In the intention-to-treat analysis,85 patients were allocated to each group, and 81 patients with STB completed the per-protocol assessment. The incidence of HDP at 30 minwas significantly lower in the STB group than in the ISB group (21.2% vs. 51.8%; P < 0.001), with no complete HDP in the STB group versus 4.7% in the ISB group. At 3 h, HDP remained lower with STB (41.2% vs. 74.1%; P < 0.001), with zero complete paralysis in the STB group. Diaphragmatic excursion reduction was significantly attenuated by STB under both resting and deep-inspiration conditions (all P < 0.001). Compared with the ISB group, the STB group yielded longer sensory blockade duration (9.29 ± 1.41 h vs. 8.90 ± 0.90 h; *P* = 0.028), lower pain scores at 6-12 h [2.0 (interquartile range, IQR 2.0-3.0) vs. 4.0 (IQR 3.0-5.0); *P* < 0.001], and less 24-hour opioid consumption (converted to intravenous morphine milligram equivalents): 9 mg (IQR 9-12) vs. 12 mg (IQR 9-17); *P* < 0.001.

Conclusion: For shoulder arthroscopy, low-volume (8 mL) and low-concentration (0.25%) STB provides superior diaphragmatic protection, prolonged analgesia, and reduced opioid requirements compared with ISB, without compromising upper-limb motor function. STB should be considered a favourable diaphragm-sparing alternative for this procedure, particularly in patients with respiratory comorbidities.

Trial registration: This trial was retrospectively registered on 7 May 2026 at the Chinese Clinical Trial Registry (No. ChiCTR2600124119, www.chictr.org.cn/hvshowproject.html?id=301390).

Introduction

Shoulder arthroscopy is increasingly performed for both degenerative and traumatic conditions[1, 2]. Although interscalene brachial plexus block (ISB) remains the analgesic gold standard, conventional high-volume regimens produce hemidiaphragmatic paralysis (HDP) in nearly all patients[3, 4]. The

superior trunk block (STB) offers diaphragm-sparing potential; however, its optimal dosing remains undefined[5, 6]. Our group first demonstrated the feasibility of STB for bilateral shoulder arthroscopy using 10 ml 0.25% ropivacaine, achieving successful anesthesia without significant diaphragmatic dysfunction[7]. Subsequently, using a biased coin design up-and-down sequential allocation trial, we determined the maximum effective volume of 0.25% ropivacaine for preventing HDP (both partial and complete) in 90% of patients (MEV_{90}) to be 7.6 mL[8]. Despite these advances, the clinical adoption of STB has been hindered by technical learning curves, and many anesthesiologists, particularly in China, continue to default on the familiar ISB technique[9]. Moreover, their impression of ISB remains largely based on traditional high-volume, high-concentration regimens[9]. Notably, data on low-volume and low-concentration ISB is scarce from the literature, precluding evidence-based technique selection.

This randomized, double-blind trial compared STB with ISB using 8 ml 0.25% ropivacaine. We sought to determine whether this optimized low-volume regimen would provide superior diaphragmatic protection while preserving analgesic efficacy, thereby addressing a critical unmet need for shoulder arthroscopy anesthesia.

Methods

2.1 Ethics Approval and Trial Registration

This prospective, double-blind, randomized controlled trial was approved by the Ethics Committee of the Second Affiliated Hospital of Naval Medical University (Approval No. 2024SL059) and was registered in the Chinese Clinical Trial Registry (ChiCTR2600124119). Written informed consent was obtained from all participants prior to enrollment.

2.2 Study Participants

Eligible participants were adults aged 40-75 years scheduled for elective arthroscopic shoulder surgery (rotator cuff repair or diagnostic arthroscopy) at our institution’s Department of Orthopedics between April 2024 and February 2025. The inclusion criteria were an American Society of Anesthesiologists (ASA) physical status of I-III. The exclusion criteria were as follows: (1) chronic obstructive pulmonary disease, prior cerebral infarction or transient ischemic attack, obstructive sleep apnea-hypopnea syndrome, or diabetes mellitus; (2) any contraindication to peripheral nerve block; (3) inability to comprehend or reliably report pain scores; and (4) inability to cooperate with grip strength or diaphragmatic mobility assessment. Protocol deviations leading to post-randomization exclusion were as follows: (1) loss to follow-up; (2) neck anatomical variations or technical difficulty in avoiding the transverse cervical artery or subclavian vein under ultrasound guidance; (3) inability to reliably measure diaphragmatic excursion after block placement (e.g., inadequate splenic window on the left side); and (4) incomplete surgery or failure to regain consciousness within 3 h after nerve block administration.

2.3 Sample Size

The primary outcome was the overall incidence of HDP, defined as partial or complete diaphragmatic dysfunction 30 min post-injection. In our preliminary open-label study of 20 patients per group, HDP occurred in 9 of 20 patients (45%) receiving ISB and in 4 of 20 patients (20%) receiving STB with 8 ml 0.25% ropivacaine. Assuming HDP incidences of 45% and 20% for the ISB and STB groups, respectively, a two-sided alpha (α) of 0.05 and a power (1 − β) of 90% were specified. The sample size was calculated using PASS (version 15.0; NCSS, LLC, Kaysville, UT, USA) with a two-proportion Z-test (pooled variance). The initial estimate required 72 evaluable participants per group. To account for 1:1 randomization and an anticipated attrition rate of 15%, 85 subjects were recruited per group, yielding a total sample size of 170.

2.4 Randomization and Blinding

The random allocation sequence was generated by an independent statistician using R software. Permuted-block randomization with variable block sizes of 4 and 6 was used to achieve a 1:1 allocation ratio between the STB and ISB groups. The statistician was not involved in patient enrollment, intervention delivery, or outcome assessment. For allocation concealment, the random group assignments were placed into sequentially-numbered, opaque, sealed envelopes. Neither study personnel nor the participant had access to the full random allocation sequence in advance. The corresponding numbered envelope for each participant was opened only immediately before administration of the nerve block intervention to reveal group assignment. Participants and all outcome assessors were blinded to group assignment; the ultrasound screen was positioned away from participants' view to prevent inadvertent disclosure of procedural details. All nerve blocks were performed by a single experienced attending anesthesiologist (ZYY), who was unblinded to the allocated block technique and solely responsible for performing the nerve block procedures, and did not participate in outcome assessment or data collection. All baseline and post-block assessments (including diaphragmatic excursion, grip strength, and pain scores) were conducted by two independent evaluators who remained blinded to group assignment throughout the study. All research personnel handling the data received training in data protection and confidentiality. The data were stored securely with restricted access.

2.5 Intervention Protocol

All patients received supplemental oxygen via a face mask at 3-6 L/min. Continuous electrocardiography, pulse oximetry (SpO_2), and bispectral index (BIS) measurements were performed. A radial arterial catheter was inserted under local anesthesia to monitor the continuous invasive blood pressure.

In both groups, 0.25% ropivacaine was prepared by diluting 2.5 ml of 1% ropivacaine with 7.5 ml of normal saline to a total volume of 10 mL.

With the patient in the supine position and the head turned 30° away from the operative side, ultrasound guidance was employed: a low-frequency curvilinear probe was used for diaphragmatic assessment, and a high-frequency linear probe for brachial plexus localization. STB group: The transducer was moved caudally to identify the convergence of the C5 and C6 nerve roots into the superior trunk, just proximal to

the origin of the suprascapular nerve. Color Doppler imaging was performed to identify and avoid the transverse cervical artery. After skin infiltration with 1 ml of 2% lidocaine, a 22-gauge block needle was advanced in the in-plane direction from the lateral to medial direction. A dual-depot injection was performed (Fig. 1A): 4 ml of 0.25% ropivacaine was deposited deep into the superior trunk, which was then repositioned superficial to the trunk, and an additional 4 ml was deposited to achieve a circumferential perineural distribution (total volume 8 mL). ISB group: At the level of the cricothyroid membrane, the transducer was moved laterally to identify the classic "traffic light" sign (C5, C6, and C7 nerve roots aligned between the anterior and middle scalene muscles). The needle was advanced in-plane from the lateral to medial direction through the middle scalene muscle. By using the two-point injection technique (Fig. 1B), 4 ml of 0.25% ropivacaine was injected deep to the C6 nerve root; the needle was then repositioned superficial to the C5 nerve root, and an additional 4 ml was injected following negative aspiration for blood (total volume 8 mL).

General anesthesia was induced using a laryngeal mask airway (LMA). Anesthesia was induced using propofol (2 mg/kg) and remifentanil (1 μg/kg, administered over 60 s). An appropriately sized LMA was inserted and ventilation was assisted until spontaneous breathing resumed. Anesthesia was maintained with sevoflurane (end-tidal MAC 0.6-1.0), while maintaining BIS values between 40 and 60. If the heart rate or mean arterial pressure increased by > 20% above the baseline, sufentanil (10 μg) was administered intravenously. Sevoflurane was tapered and discontinued prior to surgical closure. Dolasetron (12.5 mg) was administered intravenously for postoperative nausea and vomiting (PONV) prophylaxis.

Patients were transferred to the post-anesthesia care unit (PACU), where the LMA was removed upon return of full consciousness. Pain intensity was assessed using an 11-point numeric rating scale (NRS; 0 = no pain, 10 = worst imaginable pain). Diaphragmatic excursion and grip strength were reassessed 3 h post-injection. Additional assessments at 6, 12, and 24 h included pain scores (NRS), sensory block duration, opioid rescue consumption, and PONV.

2.6 Outcome Measures

The primary outcome was the incidence of HDP, which was defined as partial or complete diaphragmatic dysfunction. Diaphragmatic excursion was measured using M-mode ultrasound during deep inspiration at 30 min and 3 h post-injection. Diaphragmatic excursion and grip strength were measured 30 min and 3 h post-injection (mean of three measurements). Block duration was defined as the interval from the completion of ropivacaine injection to the first report of postoperative pain requiring analgesic intervention. HDP severity was graded as absent (normal excursion), partial (25-75% reduction from baseline), or complete (≥ 75% reduction or paradoxical movement).

Secondary outcomes included pain intensity assessed via the NRS at predefined intervals of 0–6 h, 6–12 h, and 12–24 h postoperatively; reduction in grip strength on the blocked side, which was measured using a JAMAR hydraulic hand dynamometer before block administration and at 3 h after injection; block duration, defined as the time from completion of ropivacaine injection to the first report of postoperative

pain; and cumulative opioid consumption within 24 h post-injection, expressed as intravenous morphine milligram equivalents (MME).

Statistical Analysis

The intention-to-treat (ITT) population included all 170 randomly assigned participants (85 participants allocated to the STB group and 85 participants allocated to the ISB group). The per-protocol (PP) population was used as a sensitivity analysis and excluded participants with anatomical variation (n = 2) or poor ultrasound imaging (n = 2). All analyses were performed using SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Shapiro-Wilk test. Normally distributed data are presented as mean ± standard deviation (SD) and were analyzed using independent or paired t-tests, as appropriate. Non-normally distributed data are presented as medians interquartile range (IQR) and were analyzed using the Mann-Whitney U test. Categorical variables are presented as frequencies (percentages) and were compared using the chi-squared test or Fisher's exact test, as indicated. The incidence of HDP was analyzed as a dichotomous outcome and was reported as a percentage. Differences were considered statistically significant at a two-sided p-value of < 0.05. The primary analysis followed the ITT principle, with sensitivity analyses performed using the PP population where applicable.

Results

1. Patient Characteristics and Flow

The trial was conducted at the Shanghai Changzheng Hospital from April 2024 to February 2025. A total of 188 patients scheduled for arthroscopic shoulder surgery were screened. After applying the eligibility criteria, 170 participants were enrolled and randomly assigned (Fig. 2). In the intention-to-treat analysis, 85 patients were allocated to the ISB group and 85 to the STB group. Four patients in the STB group were excluded from the per-protocol analysis due to anatomical variation (n = 2) or poor ultrasound imaging (n = 2), yielding 81 evaluable patients. Baseline characteristics were well balanced between the groups (Table 1). There were no statistically significant differences in age, sex, body mass index, ASA physical status, surgical side, or operative time (all P > 0.05).

Table 1
Patient Characteristics.

Characteristics	ISB Group	STB Group	P value
Sample size	85	81	
Age (years)	56.6 ± 8.6	58.9 ± 9.3	0.069
Sex			0.546
Female	47 (55.3%)	41(50.6%)	
Male	38 (44.7%)	40(49.4%)	
BMI (kg/m^2)	23.8 ± 2.2	23.6 ± 2.0	0.390
ASA status			0.234
I	57(67.1%)	45 (55.6%)	
II	23 (27.1%)	32 (39.5%)	
III	5 (5.8%)	4 (4.9%)	
Surgical side			0.149
Right	60 (70.6%)	65 (80.2%)	
Left	25 (29.4%)	16(19.8%)	
Duration of surgery (min)	66.2 ± 9.1	68.0 ± 7.8	0.181

Table footnote

BMI = Body mass index; ASA=American Society of Anesthesiologists.

2.1 Diaphragmatic Function

Baseline diaphragmatic excursion was comparable between the groups (Table 2). In the ISB group, resting excursion decreased from 1.89 ± 0.33 cm at baseline to 1.28 ± 0.36 cm at 30 min (32.2% reduction) and to 1.07 ± 0.25 cm at 3 h (43.2% reduction). Deep inspiration excursion decreased from 4.99 ± 0.57 cm to 2.80 ± 0.66 cm at 30 min (43.5% reduction) and to 1.96 ± 0.50 cm at 3 h (60.5% reduction). In the STB group, resting excursion decreased from 1.98 ± 0.24 cm to 1.64 ± 0.27 cm at 30 min (17.8% reduction) and to 1.50 ± 0.26 cm at 3 h (24.4% reduction). Deep inspiration excursion decreased from 4.98 ± 0.71 cm to 4.40 ± 0.65 cm at 30 min (11.3% reduction) and to 3.18 ± 0.64 cm at 3 h (35.7% reduction). The reduction in diaphragmatic excursion was significantly greater in the ISB group than in the STB group at both time points and under both respiratory conditions (all $P < 0.001$). The findings are presented in Fig. 3.

Table 2
The descent amplitude of the hemidiaphragm on the blocked side in both groups

Characteristics	State	Time point	Diaphragmatic excursion(cm)	Reduction(%)
ISB Group	Rest	Before block	1.89 ± 0.33	—
		30 min post-block	1.28 ± 0.36	32.2 ± 15.0
		3 h post-block	1.07 ± 0.25	43.2 ± 11.1
	Deep inspiration	Before block	4.99 ± 0.57	—
		30 min post-block	2.80 ± 0.66	43.5 ± 13.0
		3 h post-block	1.96 ± 0.50	60.5 ± 9.9
STB Group	Rest	Before block	1.98 ± 0.24	—
		30 min post-block	1.64 ± 0.27*	17.8 ± 8.0*
		3 h post-block	1.50 ± 0.26*	24.4 ± 10.0*
	Deep inspiration	Before block	4.98 ± 0.71	—
		30 min post-block	4.40 ± 0.65*	11.3 ± 8.0*
		3 h post-block	3.18 ± 0.64*	35.7 ± 12.1*

Table footnote

(1) * P < 0.001, compared to ISB group. (2) The symbol '—' indicates that the data has not been obtained.

2.2 Incidence of HDP

The incidence of HDP is presented in Table 3 (PP analysis) and Table 4 (ITT analysis). Based on the ITT analysis (Table 4), 30 min after injection, HDP developed in 44 out of 85 patients (51.8%) in the ISB group: 40 cases (47.1%) had partial HDP and 4 cases (4.7%) presented with complete HDP. In the STB group, 18 of 85 patients (21.2%) experienced HDP, all of which were partial episodes. At 3 h post-injection, the overall incidence of HDP rose to 74.1% (63/85) in the ISB group, consisting of 39 partial cases (45.9%) and 24 complete cases (28.2%). By contrast, the STB group had a partial HDP rate of 41.2% (35/85), with no cases of complete HDP observed.

In the PP analysis (Table 3), which excluded four patients from the STB group due to anatomical variation or poor imaging, the findings were consistent. At 30 min, HDP occurred in 44 of 85 patients (51.8%) in the ISB group (40 partial and 4 complete) and in 14 of 81 patients (17.3%) in the STB group. At

3 h, the ISB group had 63 of 85 (74.1%) HDP (39 partial, 24 complete), whereas the STB group had 31 of 81 (38.3%) HDP, all partial. No complete HDP was observed in the STB group at any of the time points.

Table 3 The incidence of HDP in two groups (PP analysis)[n, (N%)]

Time point	Characteristics(N)	Deep-inspiration		
		Partial HDP	Complete HDP	Partial/Complete HDP
30 min post-block	ISB Group(85)	40 (47.1)	4 (4.7)	44(51.8)
	STB Group(81)	14 (17.3)	0 (0.0)*	14 (17.3)*
3 h post-block	ISB Group(85)	39 (45.9)	24 (28.2)	63(74.1)
	STB Group(81)	31(38.3)	0 (0.0)*	31(38.3)*

Table footnote

*P < 0.001, Compare with ISB group.

Table 4
The incidence of HDP in two groups (ITT analysis)[n, (N%)]

Time point	Characteristics(N)	Deep-inspiration		
		Partial HDP	Complete HDP	Partial/Complete HDP
30 min post-block	ISB Group(85)	40 (47.1)	4 (4.7)	44(51.8)
	STB Group(85)	18 (21.2)	0 (0.0)*	18 (21.2)*
3 h post-block	ISB Group(85)	39 (45.9)	24 (28.2)	63(74.1)
	STB Group(85)	35(41.2)	0 (0.0)*	35(41.2)*

Table footnote

*P < 0.001, Compare with ISB group.

3. Comparison of Secondary Outcomes

3.1 Grip strength

Baseline grip strength was comparable between groups (ISB: 33.91 ± 8.87 kg; STB: 32.01 ± 10.60 kg; P = 0.222). At 3 h post-injection, grip strength was 22.40 ± 6.76 kg in the ISB group and 21.86 ± 8.56 kg in the STB group, with no significant between-group difference (P = 0.395). The relative reduction from baseline was 34.09% in the ISB group and 31.44% in the STB group (P = 0.137).

3.2 Postoperative Pain Scores

No pain was reported in either group during the interval from PACU arrival to 6 h postoperatively. Between 6 and 12 h post-injection, the median NRS score was significantly higher in the ISB group than in the STB group [4.0 (IQR 3.0-5.0) vs. 2.0 (IQR 2.0-3.0); P < 0.001]. From 12 to 24 h, NRS scores were comparable between groups [ISB: 4.0 (IQR 3.0-5.0); STB: 3.0 (IQR 3.0-4.0); P = 0.475].

3.3 Duration of Sensory Blockade

The mean duration of sensory blockade was 8.90 ± 0.90 h in the ISB group and 9.29 ± 1.41 h in the STB group (P = 0.028). The range was 6.2-11.2 h in the ISB group and 6.5-12.5 h in the STB group.

3.4 Postoperative Opioid Consumption

No intraoperative opioids were administered. During the first 24 h post-injection, the median cumulative opioid consumption was 12 mg (IQR, 9-17) MME in the ISB group and 9 mg (IQR, 9-12) MME in the STB group (P < 0.001).

3.5 Adverse Events

None of the patients in either group developed Horner's syndrome, hoarseness, local anesthetic allergy, or signs of local anesthetic systemic toxicity (LAST). Postoperative nausea and vomiting occurred in 21 of 85 patients (24.7%) in the ISB group and in 19 of 81 patients (23.5%) in the STB group, with no significant between-group differences (P = 0.851).

Discussions

This randomized, double-blind trial demonstrated that in patients undergoing shoulder arthroscopy, a low-volume (8 mL), low-concentration (0.25%) ropivacaine STB provides superior diaphragmatic protection, prolonged sensory blockade, reduced postoperative pain scores between 6 and 12 h, and lower 24-hour opioid consumption compared with ISB. Importantly, grip strength preservation at 3 h was comparable between the two groups, indicating that the diaphragm-sparing benefit of STB does not compromise upper limb motor function. No complete HDP was observed in the STB group at any time point, whereas the ISB group showed a 4.7% incidence of complete HDP at 30 min and 28.2% at 3 h.

ISB has long been regarded as the gold standard for perioperative shoulder analgesia, yet its association with phrenic nerve palsy and ipsilateral upper limb motor dysfunction remains a substantial limitation[10]. Our results align with emerging evidence that diaphragm-sparing approaches can attenuate HDP while maintaining analgesic efficacy. Notably, previous investigations of STB have predominantly employed standard volumes (10-15 mL) or even larger doses (> 15 mL)[11–13]. By standardizing both techniques at a very low volume and concentration (8 ml of 0.25% ropivacaine), the present study isolated the independent effect of the anatomical target, superior trunk versus interscalene groove, on diaphragmatic function and analgesic outcomes. This design provides a clearer mechanistic comparison than previous reports using mixed regimens, wherein confounding by volume and concentration precludes definitive conclusions.

The observed 0% incidence of complete HDP with STB coupled with a substantial reduction in partial HDP is consistent with the anatomical rationale for this technique. The superior trunk represents a more distal target situated caudal to the course of the phrenic nerve along the anterior scalene muscle[14]. Consequently, the local anesthetic deposited at this site is less likely to spread cephalad toward the phrenic nerve, even when administered in a dual-depot pattern. Conversely, ISB places the anesthetic in immediate proximity to the phrenic nerve trajectory, rendering diaphragmatic involvement nearly inevitable, albeit attenuated by low-volume delivery[15, 16]. The similar grip strength results indicate that the motor preservation observed with STB does not stem from inadequate block and that low-volume ISB also allows considerable retention of hand grip strength.

From a practical standpoint, diaphragmatic protection is particularly important in patients with respiratory comorbidities or limited pulmonary reserve, where even partial diaphragmatic impairment may precipitate clinically meaningful respiratory compromise[17, 18]. The prolonged sensory blockade and attenuated late-phase pain observed with STB translated into reduced opioid requirements, which may facilitate faster postoperative recovery and diminish opioid-related adverse effects including nausea, constipation, and respiratory depression[19, 20]. These benefits are especially relevant, given the current emphasis on opioid-sparing perioperative pathways.

Technically, our findings underscore the value of standardized anatomy-driven injection strategies. The dual-depot technique—depositing anesthetic both deep and superficial to the superior trunk—likely promotes circumferential perineural spread, enhancing block reliability even with a limited volume[21]. Meticulous ultrasound guidance, including color Doppler verification, to avoid the transverse cervical artery remains essential. Given the comparable motor outcomes and improved analgesic profile with STB, targeted training and credentialing in ultrasound-guided superior trunk identification may be warranted for anesthesiology teams that regularly perform shoulder arthroscopy.

The study’s principal strengths include the low-volume, diaphragm-sparing design, and the direct, standardized comparison of two techniques using identical anesthetic regimens. The adoption of a two-point injection approach for both blocks reduces diffusion-related variability and enhances the internal validity. Furthermore, the inclusion of clinically meaningful outcomes—HDP incidence and severity, diaphragmatic excursion, pain trajectories, opioid consumption, and functional measures—provides a comprehensive assessment of both safety and efficacy.

However, several limitations of this study warrant further investigation. First, all nerve blocks were performed by a single experienced anesthesiologist at a single center, which may limit external validity. Multicenter trials involving operators with varied experience levels are needed to confirm generalizability. Second, blinding of the performing physician was not feasible, introducing potential performance bias, although the patients and outcome assessors remained masked to group allocation. Third, diaphragmatic function was assessed by ultrasound excursion alone, which may underestimate paralysis in the presence of compensatory intercostal or accessory muscle recruitment. Complementary objective respiratory measurements (e.g., spirometry, diaphragmatic electromyography, or

transdiaphragmatic pressure monitoring) would strengthen physiological inference. Fourth, the exclusion of patients with obesity, short necks, severe cardiovascular disease, or significant anatomical variations limits the applicability to high-risk populations, warranting dedicated investigation in these subgroups. Finally, the follow-up duration was limited to 24 h; long-term functional outcomes, patient satisfaction, and time to return to daily activities remain to be evaluated.

Conclusion

In patients undergoing shoulder arthroscopy, a low-volume (8 mL), low-concentration (0.25%) STB provides superior diaphragmatic protection, prolonged sensory blockade, reduced postoperative opioid consumption, and comparable upper limb motor function preservation relative to ISB. These findings establish STB as a diaphragm-sparing alternative that enhances perioperative safety without compromising analgesic efficacy or early motor recovery. This approach may be particularly advantageous for patients with limited pulmonary reserve or other respiratory comorbidities, for whom preservation of diaphragmatic function is paramount.

Abbreviations

ASA, American Society of Anesthesiologists; BIS, bispectral index; BMI, Body mass index; CONSORT, Consolidated Standards of Reporting Trials; HDP, hemidiaphragmatic paralysis; ISB, Interscalene brachial plexus block; ITT, intention-to-treat; LMA, laryngeal mask airway; LAST, local anesthetic systemic toxicity; MME, morphine milligram equivalents; NRS, numeric rating scale; PACU, post-anesthesia care unit; PP, per-protocol; PONV, postoperative nausea and vomiting; SD, standard deviation; IQR, interquartile range; STB, superior trunk block.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from Ethics Committee of Shanghai Changzheng Hospital of Naval Medical University (Approval No.2024SL059). All methods were performed in accordance with relevant guidelines and regulations and with CONSORT recommendations. All participants provided written informed consent prior to their enrollment in this study, and consent to participate was confirmed for all included subjects.

Consent for publication

Not applicable.

Competing interests

All the authors report no conflicts of interest in this work.

Availability of data and materials

The statement specifies that deidentified individual participant data will be shared upon reasonable request with the corresponding author (Prof. Yonghua Li), beginning six months after publication.

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Authors Contributions

Yonghua Li, Na Wang, and Jiaojiao Feng conceived and designed the study. Jinxiang Zhang and Yuqiong Wang were responsible for data collection. Yangyang Zhou drafted the manuscript. Yonghua Li critically revised the manuscript for important intellectual content.

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Figures

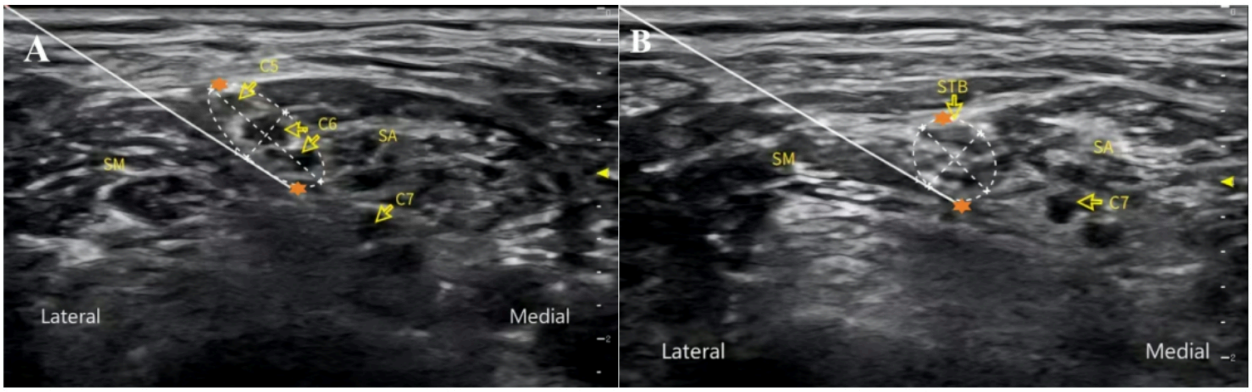


Figure 1

Ultrasound anatomy and injection site of ISB(Fig A) and STB(Fig B). SA, scalenus anterior; SM, scalenus medius; ISB, Interscalene brachial plexus block; STB, superior trunk block; C5, 5th cervical nerve root; C6, 6th cervical nerve root; C7,7th cervical nerve root. Both groups were administered medication using the two-point method. In the ISB group, 4 ml was injected deep into C6 and another 4 ml was injected superficial to C5 (A). In the STB group, 4 ml was injected deep into the superior trunk and 4 ml was injected superficial to the superior trunk(B). Orange stars mark as injection site.

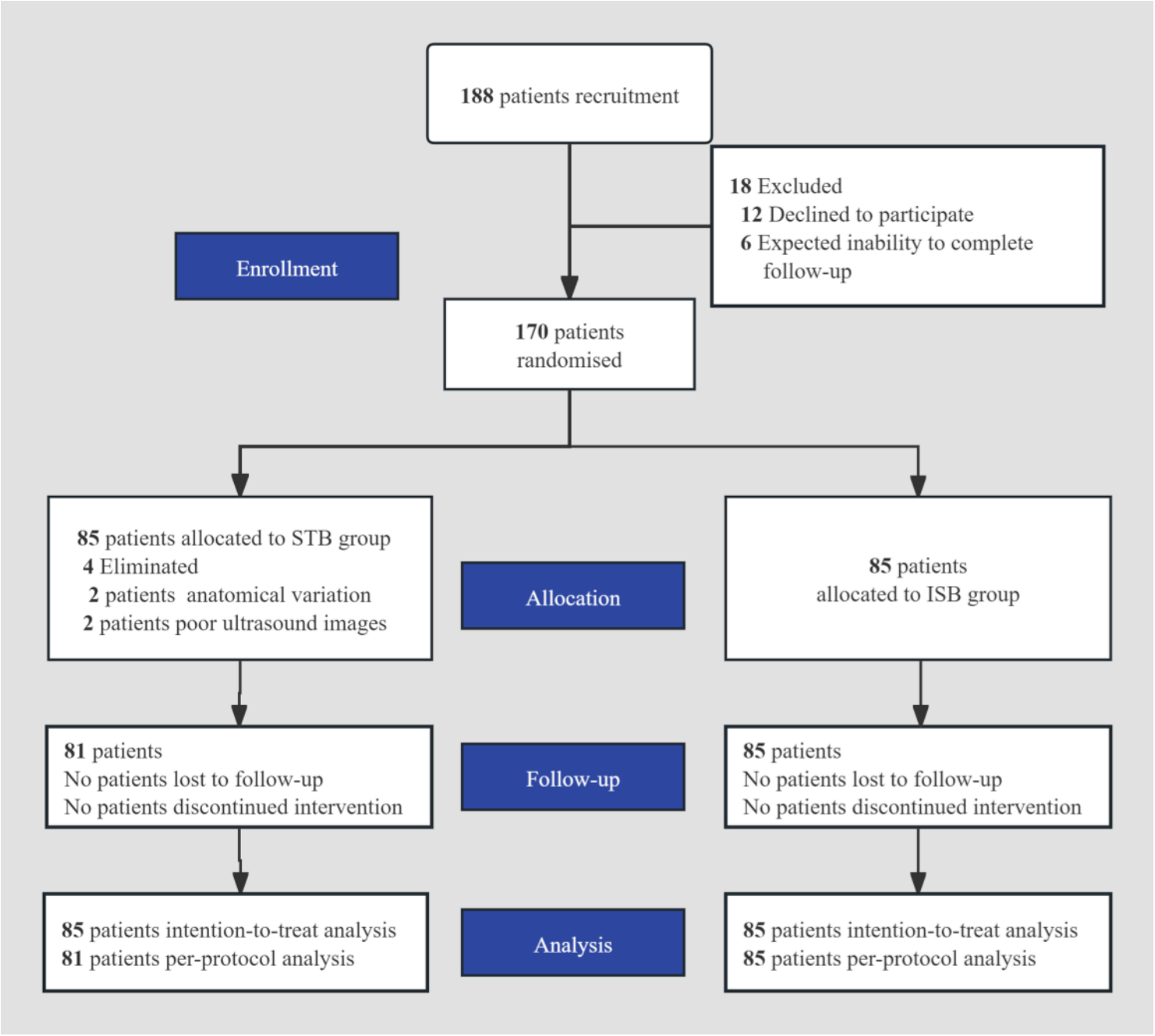


Figure 2

Consolidated Standards of Reporting Trials (CONSORT) flow diagram.

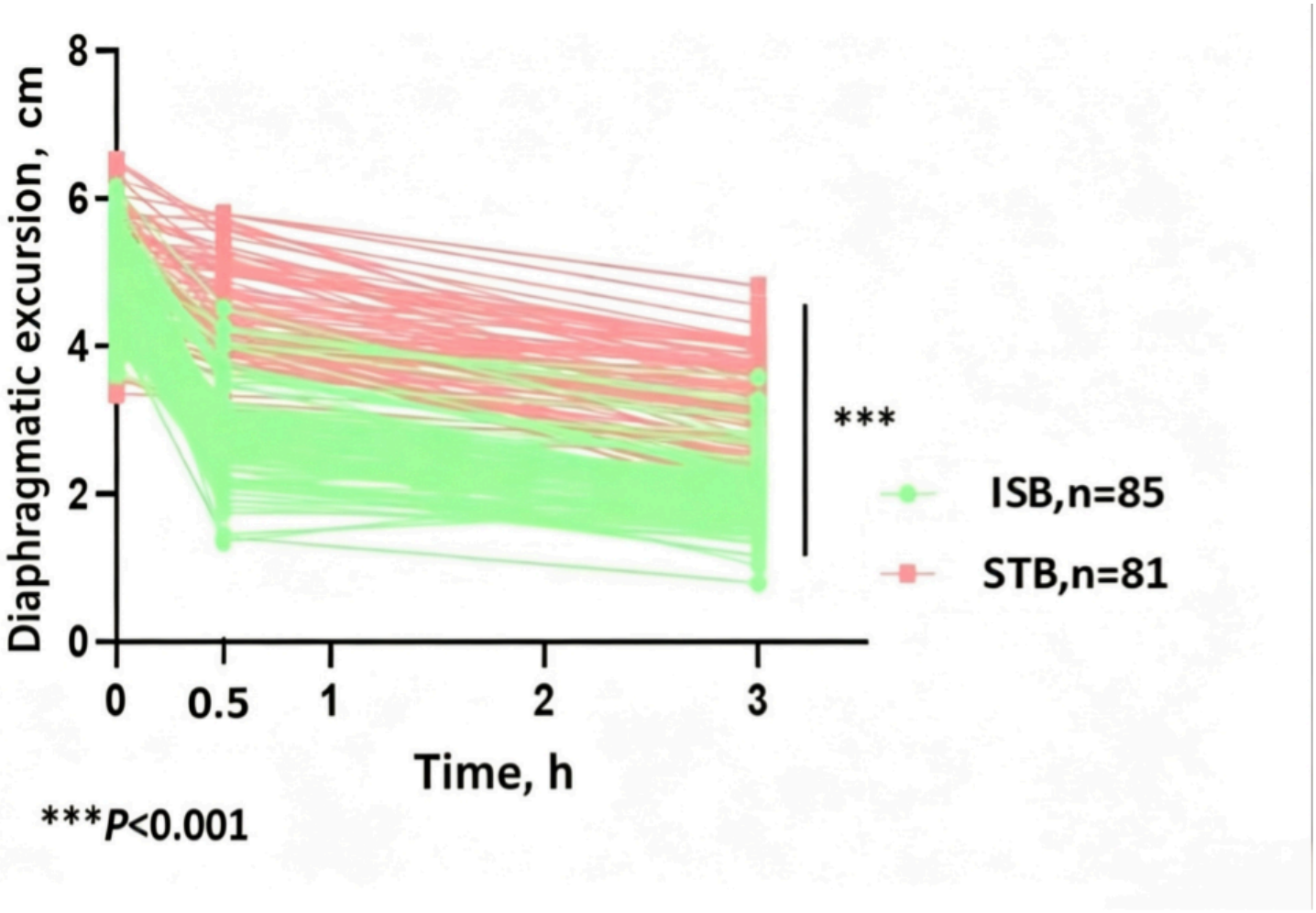


Figure 3

Comparison of Diaphragmatic Movement between Two Groups of Patients at 30 min and 3 h Deep Inhalation after Blockade. ISB group is represented by green lines; STB group is represented by red lines. *** P□0.001.

Supplementary Files

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