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ORIGINAL RESEARCH

Preoperative Stellate Ganglion Block for Postoperative Sore Throat in Patients Undergoing Double-Lumen Endotracheal Intubation: A Randomized Clinical Trial

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Background: As a common complication of double-lumen endobronchial tube (DLT) intubation during thoracic surgery, postoperative sore throat (POST) brings adverse impacts on patient recovery. Although stellate ganglion block (SGB) can modulate sympathetic tone and inflammatory reactions, its efficacy in preventing DLT-related POST is still inconclusive. This trial aimed to determine whether SGB reduces the incidence of POST at 6 h after surgery in patients undergoing DLT intubation.

Methods: In this single-center prospective randomized controlled trial, 124 patients undergoing elective thoracic surgery with left-sided DLT intubation were randomized 1:1 to two groups: the intervention group received preoperative ultrasound-guided right-sided SGB (5 mL of 0.5% ropivacaine), and the control group received standard care (ultrasound scanning without injection plus 1% tetracaine gel lubrication). The primary endpoint was the incidence of POST at 6 h after surgery.

Results: Of the 124 randomized patients, 111 eligible subjects were finally included in the full analysis. The incidence of POST at 6 h after surgery, was significantly decreased in the ultrasound-guided SGB intervention group compared with the standard care control group (14.3% vs 38.2%; RR = 0.37; 95% CI: 0.18–0.77; $P = 0.008$). This significant protective effect of SGB against POST was consistently observed at the early postoperative time point of 2 h ($P = 0.017$) and sustained up to 24 h after surgery ($P = 0.036$). SGB also significantly reduced POST severity at all time points, lowered sleep disturbance rate and improved anxiety/depression scores at 24 h after surgery (all $P < 0.05$). No between-group differences were observed in the incidence or severity of hoarseness or in other outcomes, and no notable complications occurred.

Conclusion: Preoperative ropivacaine-based SGB could reduce the incidence and severity of POST in patients for DLTs in thoracic surgery, with this protective effect persisting for at least 24 h after surgery. These preliminary results require validation in larger multicenter studies.

Clinical Trial Registration: Chinese Clinical Trial Registry, ChiCTR2400092313.

Keywords: postoperative sore throat, stellate ganglion block, anxiety, double-lumen endobronchial tube, thoracic surgery

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Introduction

Postoperative sore throat (POST) is widely recognized as one of the most frequent and patient-distressing perioperative complications secondary to general anesthesia (GA), and existing published literature has documented that the incidence of this complication varies from 12.1% to 70% depending on patient population, type of tracheal tube, intubation technique, and the timing and definition of POST assessment.[1,2] Although POST is typically self-limiting, it significantly impairs patient satisfaction and the quality of postoperative recovery, and has garnered considerable attention from anesthesiologists in recent years.[3–13]

Patients undergoing video-assisted thoracic surgery requiring double-lumen endobronchial tube (DLT) intubation represent an extremely high-risk population for POST.[14,15] DLTs are routinely utilized to establish one-lung ventilation (OLV) during thoracic surgical procedures, as they facilitate lung collapse and precise exposure of the operative site, thereby providing an optimal surgical field for thoracic interventions.[14,16,17] A prominent limitation of DLT use, however, is its larger outer diameter and greater rigidity; additionally, optimal tube positioning often necessitates repeated adjustments with a fiberoptic bronchoscope (FB) following intubation.[14,18] These factors collectively cause pronounced mechanical trauma to the pharyngeal mucosa, vocal cords, and tracheal mucosa, triggering a local inflammatory cascade and neurogenic inflammation driven by sympathetic overactivation, thereby contributing to both the high incidence and the prolonged duration of POST. Existing clinical studies have demonstrated that 41.5% to 70% of patients report moderate to severe POST within 6 hours after DLT intubation, and a considerable proportion of these patients experience persistent POST symptoms for more than 24 hours.[19–21]

Several prophylactic strategies have been developed to mitigate DLT-associated POST, including pharmacological interventions (eg, preoperative dexamethasone,[22] licorice gargle,[23] esketamine gargle,[24] magnesium sulfate[5]), non-pharmacological and technical modifications (eg, video DLTs,[25] two-handed jaw thrust,[26] fibreoptic-guided advance DLTs,[27] 180° rotation technique,[20] thermal softening of DLTs[21]), and our previously reported preoperative ultrasound-guided block of the internal branch of the superior laryngeal nerve (SLNB).[28] While these approaches have demonstrated varying degrees of clinical efficacy, they all harbor inherent limitations. For instance, SLNB only achieves sensory denervation of supraglottic structures, leaving the subglottic airway—innervated by the recurrent laryngeal nerve—unprotected; additionally, its prophylactic effect against POST over extended postoperative timeframes (eg, 24 h) is limited due to the intrinsic pharmacodynamic properties of local anesthetics (LA). Furthermore, none of these interventions directly target the sympathetic overactivation and neurogenic inflammation triggered by DLT-induced mechanical trauma. This trauma initiates robust sympathetic drive, which promotes the release of proinflammatory mediators, amplifies nociceptive signaling, and prolongs pain sensitization. This sympathetic-mediated cascade represents a core mechanism sustaining POST persistence, yet it remains unaddressed by current prophylactic strategies, particularly for DLTs.

Stellate ganglion block (SGB) has garnered increasing attention for its capacity to modulate sympathetic tone and suppress the systemic inflammatory response.[29] By blocking sympathetic efferent fibers and reducing the release of proinflammatory cytokines, SGB exerts pleiotropic effects that extend beyond simple sympathetic blockade, including analgesia, post-traumatic stress disorder (PTSD) management, and improved sleep quality and cognitive function.[29–32] Of note, a recent randomized controlled trial (RCT) has documented that preoperative SGB can markedly reduce both the incidence and severity of POST after tracheal intubation in patients undergoing lumbar spinal surgery.[33] However, whether these beneficial effects can be extended to the high-risk population of patients undergoing thoracic surgery with DLT intubation remains elusive. Beyond its potential airway-protective properties, SGB may confer additional advantages to thoracic surgical patients, such as improvements in sleep and emotional status.

Therefore, we hypothesized that preoperative SGB would reduce the incidence and severity of POST in patients undergoing thoracic surgery with left-sided DLT intubation. Secondary objectives included exploring its effects on hoarseness, postoperative sleep quality, anxiety/depression status, and safety outcomes. This study aims to provide a novel clinical strategy and high-level evidence for the prevention of DLT-related POST.

Methods

Study Design

This single-center prospective randomized controlled trial was performed at The Second Qilu Hospital of Shandong University (Jinan, China) from December 2024 to December 2025, enrolling 124 patients undergoing thoracic surgery under GA. The full trial protocol with full methodological details has been reported in our previously published work.[34]

Ethical Approval

Full ethical approval for this study protocol was granted by the Institutional Review Board of the Second Qilu Hospital of Shandong University (approval number: KYLL-2024-880) on October 31, 2024. Prior to the initiation of patient recruitment, this trial was prospectively registered in the Chinese Clinical Trial Registry (registration number: ChiCTR2400092313; registration date: November 14, 2024). All study procedures were implemented in strict compliance with the ethical principles set forth in the Declaration of Helsinki. Written informed consent was acquired from every eligible participant before recruitment into the trial, and the entire research process was conducted in full adherence to the Consolidated Standards of Reporting Trials (CONSORT) 2025 guidelines.

Patients

Eligible patients were aged ≥18 years, ASA physical status I–III, scheduled for elective thoracic surgery requiring right-sided OLV via left-sided DLT intubation, consistent with the published protocol.[34] Exclusion criteria included: patient refusal; contraindications to GA or SGB (coagulopathy, local/systemic infection); predicted difficult airway; preoperative sore throat/cough; upper respiratory tract infection within 2 weeks; prior oral/pharyngeal surgery; asthma/ chronic obstructive pulmonary disease (COPD); hypertension/coronary artery disease (CAD) with long-term hemodynamic medication use; cortisol-related metabolic disorders; severe hepatic/renal dysfunction; diabetes or poor glycemic control; severe bradycardia, sick sinus syndrome or high-grade atrioventricular block; and severe cognitive/language impairment.[34]

Randomization and Blinding

Allocation concealment was performed using sequentially numbered opaque sealed envelopes, generated with a 1:1 allocation ratio via the Sealed Envelope online randomization tool (https://www.sealedenvelope.com/simple-randomiser/v1/lists) with block sizes of 2 and 4. Envelopes were opened only by an independent research anesthesiologist immediately before the scheduled SGB procedure. This anesthesiologist had no involvement in any other study-related procedures throughout the trial. All SGB procedures were conducted by a single senior anesthesiologist with extensive experience in regional anesthesia and ultrasound-guided nerve blocks. The anesthesiologist performing DLT intubation was aware of group allocation solely due to the requirement for tracheal lubrication during DLT intubation in the control group; however, this individual had no involvement in any other trial-related procedures. All other study staff, intraoperative anesthesia providers, independent outcome assessors, and follow-up researchers remained fully blinded to group allocation for the entire study.

Interventions

Eligible participants were allocated at a 1:1 ratio via randomization to either the SGB group or the control group. For patients allocated to the SGB group, right-sided SGB was administered 30 minutes before the initiation of GA. Given that all patients underwent right-sided thoracic surgery requiring left-sided DLTs, right-sided SGB was chosen for its superior perioperative safety and for its ability to deliver the block ipsilaterally to the operative side, where surgical stress and sympathetic activation are most pronounced.[33,35] Patients were positioned supine with the head slightly left-rotated. A 6–13 MHz high-frequency linear ultrasound transducer was placed transversely at the cricoid cartilage level, then moved laterally to identify the C6 vertebral transverse process. The probe was moved caudally to the C7 vertebral level until the C6 anterior tubercle was no longer visible. After negative aspiration to rule out intravascular or intrathecal injection, 5 mL of 0.5% ropivacaine was injected at the surface of the longus colli muscle beneath its anterior fascia, with

the full procedure performed in strict accordance with our previously published study protocol (Figure 1).[34] Successful SGB was confirmed by the onset of complete Horner's syndrome. The control group received ultrasound-guided stellate ganglion scanning without injection, plus 1% tetracaine gel lubrication before intubation as standard POST prevention care. The SGB group did not receive tetracaine gel lubrication.

Perioperative Anesthesia Management

Standard intraoperative monitoring included invasive blood pressure, HR, EEG, pulse oximetry and bispectral index (BIS). GA was induced with intravenous sufentanil (0.3 $\mu g \cdot kg^{-1}$), propofol (1.5–3.0 $mg \cdot kg^{-1}$) and rocuronium bromide (0.7 $mg \cdot kg^{-1}$) for neuromuscular blockade, with 100% oxygen assisted ventilation during induction.

Left-sided DLT intubation was performed by an experienced attending anesthesiologist using direct laryngoscopy with a curved Macintosh blade and a disposable left-sided DLT, with the patient's head supported on a headrest. The DLT size was chosen according to institutional guidelines based on patient sex and height.[28] Once the bronchial tip had passed through the glottis, the stylet was removed; the DLT was then rotated 90° counterclockwise to direct the bronchial tip toward the left main bronchus and advanced to the pre-estimated depth.[28] If significant resistance was encountered at the glottis, the tube was further rotated counterclockwise up to 180° to guide the tracheal lumen anteriorly, and advancement was re-attempted.[28] Correct positioning was confirmed by fiberoptic bronchoscopy after the patient was placed in the lateral decubitus position. Only patients successfully intubated on the first attempt were included.

OLV was delivered with a tidal volume (TV) of 5–7 $mL \cdot kg^{-1}$, respiratory rate of 14–16 breaths/min, and positive end-expiratory pressure (PEEP) of 3–10 cmH_2O. Anesthesia was maintained with sevoflurane (1–2% in 50% oxygen), propofol, remifentanil, and supplemental rocuronium as needed, with BIS values kept between 40 and 60. Vasoactive agents were titrated as needed to maintain hemodynamics within ± 20% of pre-induction baselines. Upon completion of surgery, the DLT was extubated once adequate spontaneous respiration was restored, defined as a tidal volume > 6 $mL \cdot kg^{-1}$, SpO_2 > 95%, BIS > 90, and muscle strength recovery to ≥ grade IV.

As part of the standard perioperative analgesic protocol, all patients received an ultrasound-guided T5–T6 thoracic paravertebral block with 10–15 mL of 0.5% ropivacaine before induction of GA. Postoperative pain was managed with patient-controlled intravenous analgesia (PCIA) containing sufentanil 100 μg, ondansetron 8 mg, and 0.9% normal saline to a total volume of 100 mL. Rescue analgesia (NSAIDs, oral analgesics, intravenous pethidine) was given as needed to maintain resting VAS pain scores < 4.

Study Outcomes

The primary outcome was the incidence of POST at 6 h after surgery.[26,28] POST and hoarseness were assessed using a 4-grade scale (none, mild, moderate, severe) at 2, 6, and 24 h postoperatively (Supplementary Table 1).[28] Secondary outcomes included: (1) incidence of postoperative sore throat at 2 and 24 h; (2) severity of POST at 2, 6, and 24 h; (3) incidence and severity of hoarseness at 2, 6, and 24 h (Supplementary Table 1); (4) sleep disturbance assessed using the

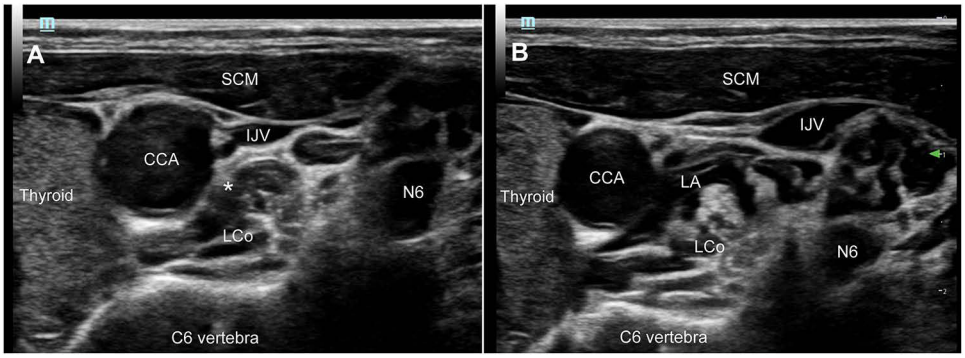

Figure 1 Ultrasound-guided SGB. (**A**) Sonographic illustration of SGB. (**B**) Post SGB injection. * Injection site of LA.
Abbreviations: SGB, stellate ganglion block; SCM, sternocleidomastoid muscle; LCo, longus colli; LCap, longus capitis muscle; CCA, common carotid artery; IJV, internal jugular vein; LA, local anesthetics; N6, C6 nerve root.

Numeric Rating Scale (NRS)-sleep and Athens Insomnia Scale (AIS) preoperatively and on postoperative day 1; (5) anxiety and depression assessed using the Hospital Anxiety and Depression Scale (HADS) preoperatively and at 24 h; and (6) intraoperative hemodynamic parameters.

Exploratory outcomes included duration of post-anesthesia care unit (PACU) stay and length of postoperative hospital stay. Safety outcomes covered perioperative adverse events, especially SGB procedure-related complications (LA systemic toxicity, hematoma, infection, pneumothorax, recurrent laryngeal or phrenic nerve block, and brachial plexus block).

Sample Size Calculation

Sample size was calculated using chi-square test based on previously published studies reporting an incidence of postoperative sore throat at 6 h after DLT intubation ranging from 41.5% to 59%, with a mean incidence of 50.25%.[26,28] Based on previous publications, we hypothesized that preoperative SGB would yield an absolute risk reduction (ARR) of 30 percentage points in the incidence of POST, from 50.25% to 20.25%.[28,33,36,37] Sample size calculation was performed with a two-sided α of 0.05 and 90% statistical power, requiring 49 patients per group. Considering a 20% anticipated dropout rate, 62 patients were enrolled in each group, with a total sample size of 124 participants. All calculations were completed using PASS 15.0 software (NCSS, LLC., Kaysville, UT, USA).

Statistical Analysis

Baseline balance was assessed using absolute standardized differences (ASD), with a value ≥ 0.352 ($1.96 \times \sqrt{[n_1 + n_2]/[n_1 \times n_2]}$) defined as imbalance.[38] The Kolmogorov–Smirnov test was used to test the normality of continuous variables. Normally distributed data were presented as mean ± SD and compared via independent-samples t tests; non-normally distributed data were reported as median (IQR) and compared via Mann–Whitney *U*-tests. Treatment effects were presented as risk/mean/median differences with 95% CIs, calculated using the Hodges–Lehmann estimator. Categorical variables were described as counts (percentages) and compared via chi-square or Fisher's exact test, with between-group differences reported as RRs and 95% CIs. Time-to-event outcomes (postoperative hospital stay) were analyzed via Kaplan–Meier curves and Log rank test, with HRs and 95% CIs estimated by univariable Cox regression.

To evaluate the effect of SGB on POST and hoarseness, generalized estimating equations (GEEs) were used to analyze the repeated measurement data.[39] For the incidence of POST and hoarseness (a binary outcome), the model was specified with a Poisson distribution, a log link function, and an exchangeable working correlation structure to directly estimate the relative risk (RR) and its 95% confidence interval. For the severity of POST and hoarseness, a cumulative logit GEE (proportional odds model) with an independent working correlation structure was employed to estimate the cumulative odds ratio (OR) and its 95% confidence interval. All models included group (SGB vs control) and time (2 h, 6 h, and 24 h, with 2 h as the reference).

Post-hoc subgroup analyses were conducted for the primary outcome (POST at 6 h) across the following clinically relevant subgroups: sex (male vs female), age (< 65 y vs ≥ 65 y), smoking status (non-smoker vs smoker), ASA physical status (II vs III), Cormack-Lehane grade (I vs II), duration of surgery (< 120 min vs ≥ 120 min), and DLT size (35Fr vs 37Fr). Treatment-covariate interactions were tested via logistic regression, with $P < 0.10$ defined as a significant interaction.[40] No multiple comparison correction was performed for secondary and exploratory outcomes, and all related results should be interpreted as exploratory.

All statistical tests were two-sided, with $P < 0.05$ considered statistically significant. Analyses were performed using SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA) and RStudio 4.1.0 (RStudio, Boston, MA, USA) by two blinded biostatisticians.

Results

Study Population and Baseline Characteristics

Between December 2024 and December 2025, 143 elective thoracic surgery patients were screened for eligibility. 19 were excluded pre-randomization (18 ineligible, 1 declined participation), and 124 eligible patients were randomized 1:1

to the SGB group (n = 62) and control group (n = 62). In the SGB group, 6 patients were excluded after randomization due to Cormack–Lehane grade 3 (n = 3), failed first intubation attempt (n = 2), or conversion to thoracotomy (n = 1), leaving 56 patients for final analysis. In the control group, 7 patients were excluded due to Cormack–Lehane grade 3 (n = 3), failed first intubation attempt (n = 3), or ventilator therapy with tube after surgery (n = 1), leaving 55 patients for final analysis (Figure 2). The final analysis therefore included 111 patients (56 in the SGB group and 55 in the control group).

Baseline demographic and clinical characteristics were comparable between the two groups (Table 1). The median age was 60 years (IQR: 55–65) in the SGB group and 60 years (IQR: 53–67) in the control group. Female patients comprised 58.9% and 50.9% of the SGB and control groups, respectively. BMI, smoking history, baseline Athens Insomnia Scale scores, and HADS scores were comparable between groups. No significant between-group differences were observed in surgical characteristics, including surgery type, operation duration, intraoperative sufentanil equivalent, ASA status, Cormack–Lehane grade, DLT size, time to achieve intubation, and duration of intubation.

Primary and Secondary Outcomes

The incidence of POST at 6 h after surgery was significantly lower in the SGB group than the control group (14.3% [8/56] vs 38.2% [21/55]; RR = 0.37; 95% CI 0.18–0.77; $P = 0.008$; Table 2 and Figure 3). Analysis for the severity of POST demonstrated a consistent benefit, with a cumulative OR of 0.24 (95% CI: 0.10 to 0.61; $P = 0.002$) for the SGB group compared with controls at 6 h postoperatively (Table 2 and Figure 3).

The beneficial effect of SGB on POST was also observed at 2 h and 24 h after surgery. At 2 h postoperatively, 11 patients (19.6%) in the SGB group reported POST compared with 23 patients (41.8%) in the control group (RR = 0.47;

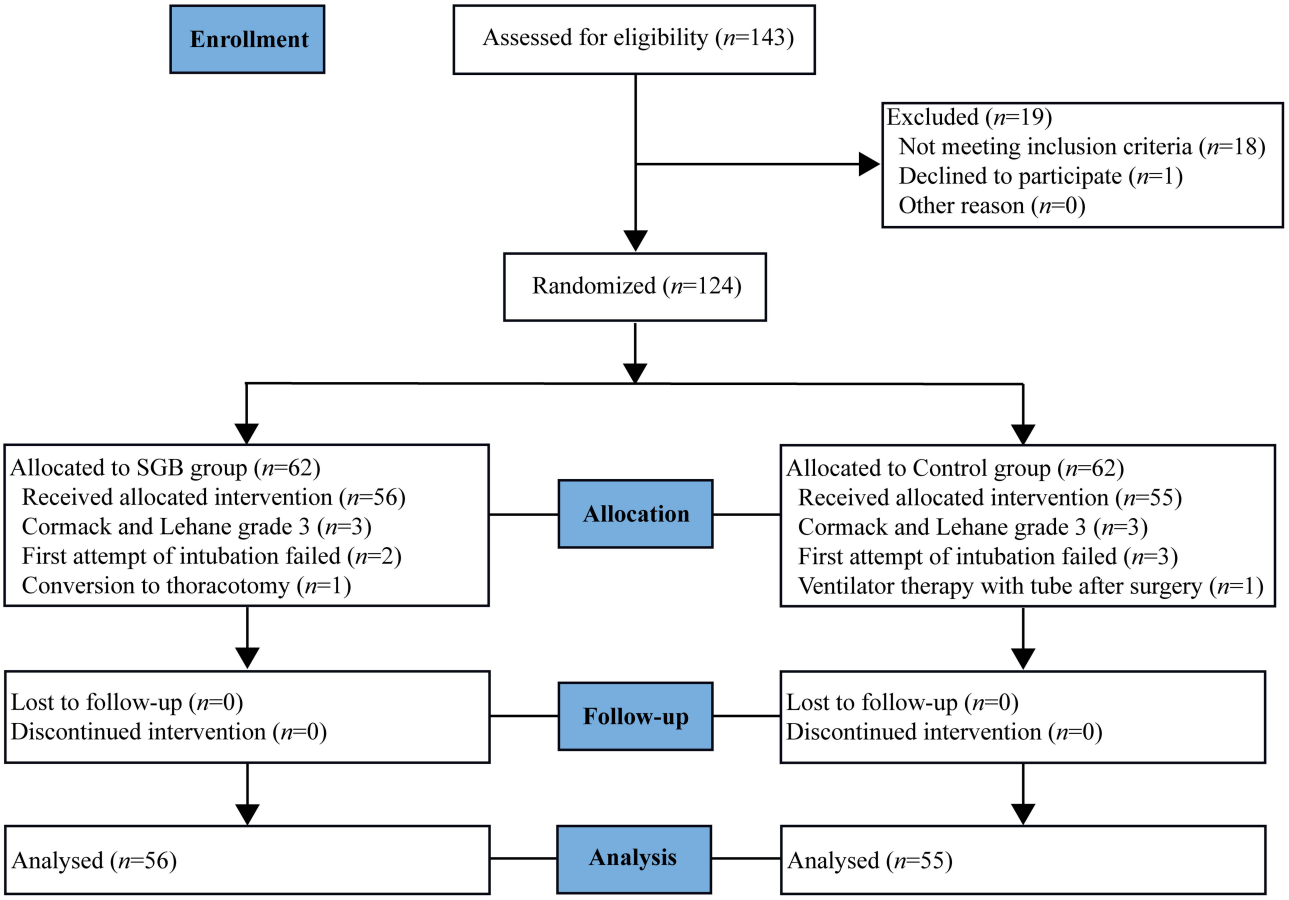

Figure 2 CONSORT flow diagram of patient enrollment, randomization, and follow-up.

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Table 1 Demographics and Baseline Characteristics

	SGB (n = 56)	Control (n = 55)	ASD[a]
Sex			0.081
Male	23 (41.1)	27 (49.1)	
Female	33 (58.9)	28 (50.9)	
Patient specifications			
Age, yr	60 [55–65]	60 [53–67]	0.052
Height, cm	165 (7)	167 (9)	0.171
Weight, kg	67 (10)	68 (13)	0.134
BMI, kg m^{-2}	24.5 (3.4)	24.5 (3.4)	0.011
Smoking history[b]	16 (28.6)	22 (40.0)	0.120
AIS score	4 [2–8]	3 [1–8]	0.103
HADS-A score	5 [3–9]	4 [2–9]	0.024
HADS-D score	4 [2–7]	4 [2–9]	0.118
Surgery			
Type of surgery			0.103
Wedge resection	32 (57.1)	36 (65.5)	
Segmentectomy	7 (12.5)	4 (7.3)	
Lobectomy	17 (30.4)	15 (27.3)	
Duration, min	85 [60–120]	70 [52–119]	0.112
Intraoperative sufentanil equivalent, μg[c]	69 [59–79]	64 [55–83]	0.010
Anesthesia			
ASA physical status			0.096
1	0 (0.0)	1 (1.8)	
2	34 (60.7)	33 (60.0)	
3	22 (39.3)	21 (38.2)	
Endotracheal intubation			
Cormack and Lehane grade			0.017
1	43 (76.8)	43 (78.2)	
2	13 (23.2)	12 (21.8)	
DLT size			0.065
35Fr	26 (46.4)	22 (40.0)	
37Fr	30 (53.6)	33 (60.0)	
Time to achieve endotracheal intubation (s)	65.0 (12.6)	67.9 (12.9)	0.232
Duration of intubation (min)	132 (40)	127 (48)	0.108

Notes: Data are number of patients (%), median (inter-quartile range) or mean (standard deviation). [a]An ASD ≥ 0.352 is considered imbalanced between the two groups; [b]Smoking 10 cigarettes per day for at least 1year, either former or current smoker; [c]Converted to intravenous sufentanil equivalent: 1 μg sufentanil (i.v.) = 10 μg remifentanil (i.v.).

Abbreviations: SGB, stellate ganglion block; ASD, absolute standardized difference; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); ASA, American Society of Anesthesiologists; AIS, Athens Insomnia Scale; HADS-A, Hospital Anxiety and Depression Scale - Anxiety subscale; HADS-D, Hospital Anxiety and Depression Scale - Depression subscale; DLT, double-lumen endobronchial tube.

95% CI: 0.25 to 0.87; P = 0.017; Table 2). We also found a significant reduction in severity at 2 h after surgery (cumulative OR = 0.31; 95% CI: 0.14 to 0.72; P = 0.007). At 24 h postoperatively, the incidence of POST remained lower in the SGB group (6 patients, 10.7%) than in the control group (15 patients, 27.3%) (RR = 0.39; 95% CI: 0.16 to 0.94; P = 0.036), with corresponding severity analysis showing cumulative OR = 0.32 (95% CI: 0.11 to 0.89; P = 0.030) (Table 2 and Figure 3). No significant differences were observed between groups in the incidence or severity of hoarseness at any assessed time point (all P > 0.05) (Table 2).

Sleep disturbance was significantly less frequent in the SGB group at 24 h postoperatively. Twenty-two patients (39.3%) in the SGB group met criteria for sleep disturbance, compared with 35 patients (63.6%) in the control group (RR = 0.62; 95% CI: 0.42 to 0.91; P = 0.010; Table 2). Patients in the SGB group also demonstrated significantly lower HADS-A score (median difference [MD] −2.00; 95% CI: −3.00 to 0.00; P = 0.006) and HADS-D scores (MD −2.00;

Table 2 Efficacy Outcomes

	SGB (n = 56)	Control (n = 55)	Effect Size (95%CI)*	*P*-value
Primary and secondary endpoints				
POST				
2 h after surgery (none/mild/moderate/severe)[a]	11 (45/9/2/0)	23 (32/13/9/1)	RR = 0.47 (0.25 to 0.87)	0.017
6 h after surgery (none/mild/moderate/severe)[b]	8 (48/7/1/0)	21 (34/11/9/1)	RR = 0.37 (0.18 to 0.77)	0.008
24 h after surgery (none/mild/moderate/severe)[c]	6 (50/6/0/0)	15 (40/11/4/0)	RR = 0.39 (0.16 to 0.94)	0.036
Hoarseness				
2 h after surgery (none/mild/moderate/severe)[d]	6 (50/3/2/1)	6 (49/4/1/1)	RR = 0.98 (0.34 to 2.87)	0.982
6 h after surgery (none/mild/moderate/severe)[e]	6 (50/3/2/1)	6 (49/4/2/0)	RR = 0.98 (0.34 to 2.87)	0.982
24 h after surgery (none/mild/moderate/severe)[f]	4 (52/4/0/0)	5 (50/4/1/0)	RR = 0.79 (0.22 to 2.79)	0.786
Sleep disturbance at 24 h after surgery[†]	22 (39.3)	35 (63.6)	RR = 0.62 (0.42 to 0.91)	0.010
HADS-A score at 24 h after surgery	3 [1–4]	5 [2–8]	MD = −2.00 (−3.00 to 0.00)	0.006
HADS-D score at 24 h after surgery	3 [1–4]	4 [2–6]	MD = −2.00 (−3.00 to 0.00)	0.006
Exploratory analysis				
Duration of PACU time, min	25.7 (5.3)	26.8 (5.0)	MD = −1.14 (−3.06 to 0.78)	0.243
Duration of postoperative hospital time, d	4 [3–6]	4 [3–5]	HR = 1.26 (0.87 to 1.83)	0.128

Notes: Data are number of patients (%), median (inter-quartile range) or mean (standard deviation). *Compared with the Control group, the incidence of POST or hoarseness in the SGB group. [a]Cumulative OR (95% CI) = 0.31 (0.14–0.72), *P* = 0.007 for the severity of sore throat at 2 h after surgery (SGB vs Control); [b]Cumulative OR (95% CI) = 0.24 (0.10–0.61), *P* = 0.002 for the severity of sore throat at 6 h after surgery (SGB vs Control); [c]Cumulative OR (95% CI) = 0.32 (0.11–0.89), *P* = 0.030 for the severity of sore throat at 24 h after surgery (SGB vs Control); [d] Cumulative OR (95% CI) = 1.00 (0.30–3.28), *P* = 0.998 for the severity of hoarseness at 2 h after surgery (SGB vs Control); [e] Cumulative OR (95% CI) = 1.01 (0.31–3.31), *P* = 0.994 for the severity of hoarseness at 6 h after surgery (SGB vs Control); [f] Cumulative OR (95% CI) = 0.76 (0.19–3.03), *P* = 0.699 for the severity of hoarseness at 24 h after surgery (SGB vs Control); [†]Sleep disturbance is defined as an NRS-sleep score of 6 points or higher or an AIS score of 6 points or higher.
Abbreviations: SGB, stellate ganglion block; CI, confidence interval; POST, postoperative sore throat; HADS-A, Hospital Anxiety and Depression Scale - Anxiety subscale; HADS-D, Hospital Anxiety and Depression Scale - Depression subscale; PACU, post-anesthesia care unit; MD, mean difference; RR, relative risk; HR, hazard ratio.

95% CI: −3.00 to 0.00; *P* = 0.006) at 24 h after surgery compared with controls (Table 2). No significant differences were observed between groups in intraoperative hemodynamic parameters, including SBP, DBP and HR (all *P* > 0.05; Supplementary Figure 1).

Exploratory Outcomes

Duration of post-anesthesia care unit stay was comparable between groups (mean 25.7 ± 5.3 min in the SGB group vs 26.8 ± 5.0 min in the control group; MD = −1.14; 95% CI: −3.06 to 0.78; *P* = 0.243). Similarly, the length of postoperative hospital stay did not differ significantly between groups (median 4 days, IQR: 3–6 in the SGB group vs 4 days, IQR: 3–5 in the control group; HR = 1.26; 95% CI: 0.87 to 1.83; *P* = 0.128; Table 2) (Table 2 and Figure 4).

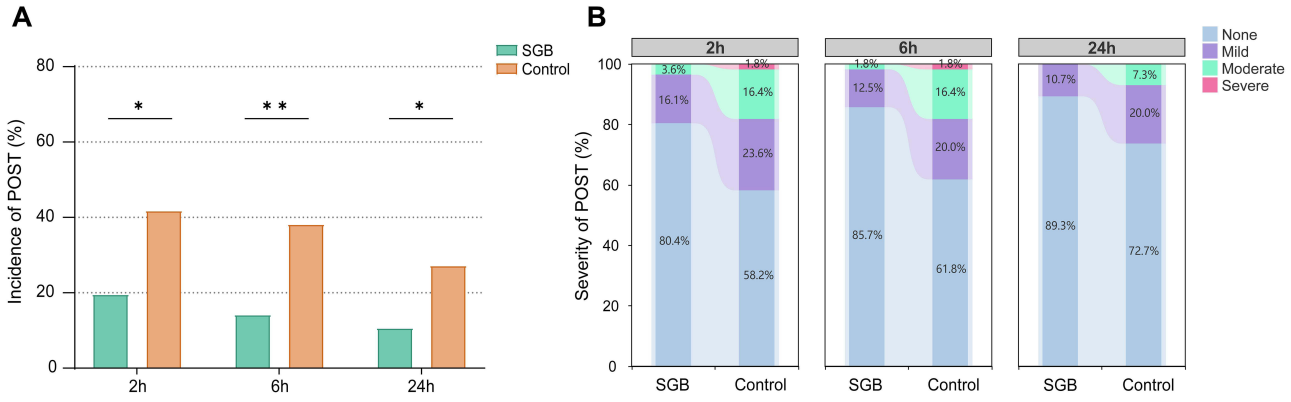

Figure 3 Incidence (**A**) and severity (**B**) of POST. *P < 0.05; **P < 0.01.
Abbreviations: POST, postoperative sore throat; SGB, stellate ganglion block.

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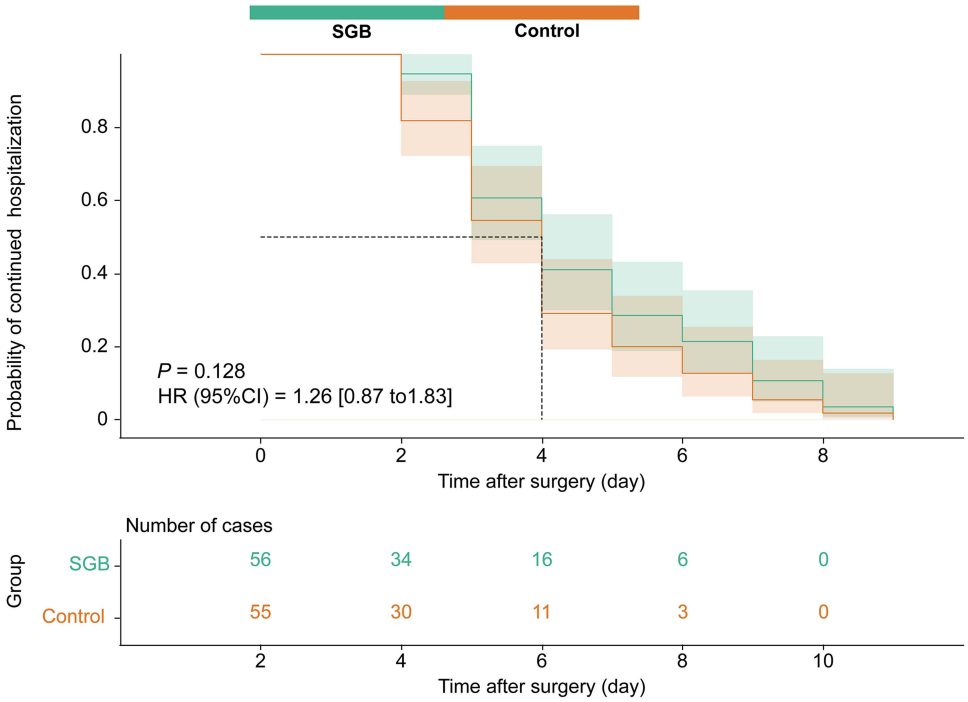

Figure 4 Kaplan-Meier curve and Log rank test of the postoperative hospital stay.

Subgroup Analysis

Subgroup analyses were performed to explore potential heterogeneity in treatment effect on the primary outcome (POST at 6 h) across clinically relevant subgroups (Figure 5). A significant treatment-by-covariate interaction was observed for duration of surgery (<120 min vs ≥120 min, *P* for interaction = 0.017). The protective effect of SGB was more pronounced in patients with shorter surgical duration compared with those with longer duration. No significant interactions were detected for sex (male vs female, *P* for interaction = 0.465), age (< 65y vs ≥ 65 y, *P* for interaction = 0.906), smoking status (nonsmoker vs smoker, *P* for interaction = 0.815), ASA classification status (II vs III, *P* for interaction = 0.171), Cormack–Lehane grade (I vs II, *P* for interaction = 0.427), or DLT size (35Fr vs 37Fr, *P* for interaction = 0.211).

Safety Outcomes

Safety outcomes were similar between groups (Table 3). Hypotension occurred in 16 patients (28.6%) in the SGB group and 14 patients (25.5%) in the control group ($P = 0.712$). Recurrent laryngeal nerve block occurred in 3 patients (5.4%) in the SGB group, with no cases in the control group ($P = 0.177$). All cases of recurrent laryngeal nerve block were transient and resolved spontaneously within 24 h without clinical sequelae. No cases of local anesthetic systemic toxicity, hematoma, puncture-related infection, pneumothorax, phrenic nerve block, or brachial plexus block were observed in either group. Hypertension, bradycardia, tachycardia, and desaturation were also comparable between groups (all $P > 0.05$).

Discussion

To our knowledge, this is the first RCT assessing the preventive effect of preoperative ultrasound-guided SGB on POST in DLT intubation patients. Results demonstrated that SGB significantly reduced both the incidence and severity of POST over the first 24 postoperative hours compared with control group. Furthermore, SGB conferred clinically meaningful improvements in sleep quality and emotional well-being at 24h after surgery; however, it did not significantly affect the incidence and severity of hoarseness.

POST represents the most frequently reported patient complaint among individuals undergoing thoracic surgery with DLT placement, and it remains a highly prevalent adverse event following DLTs under GA.[28] POST following DLT

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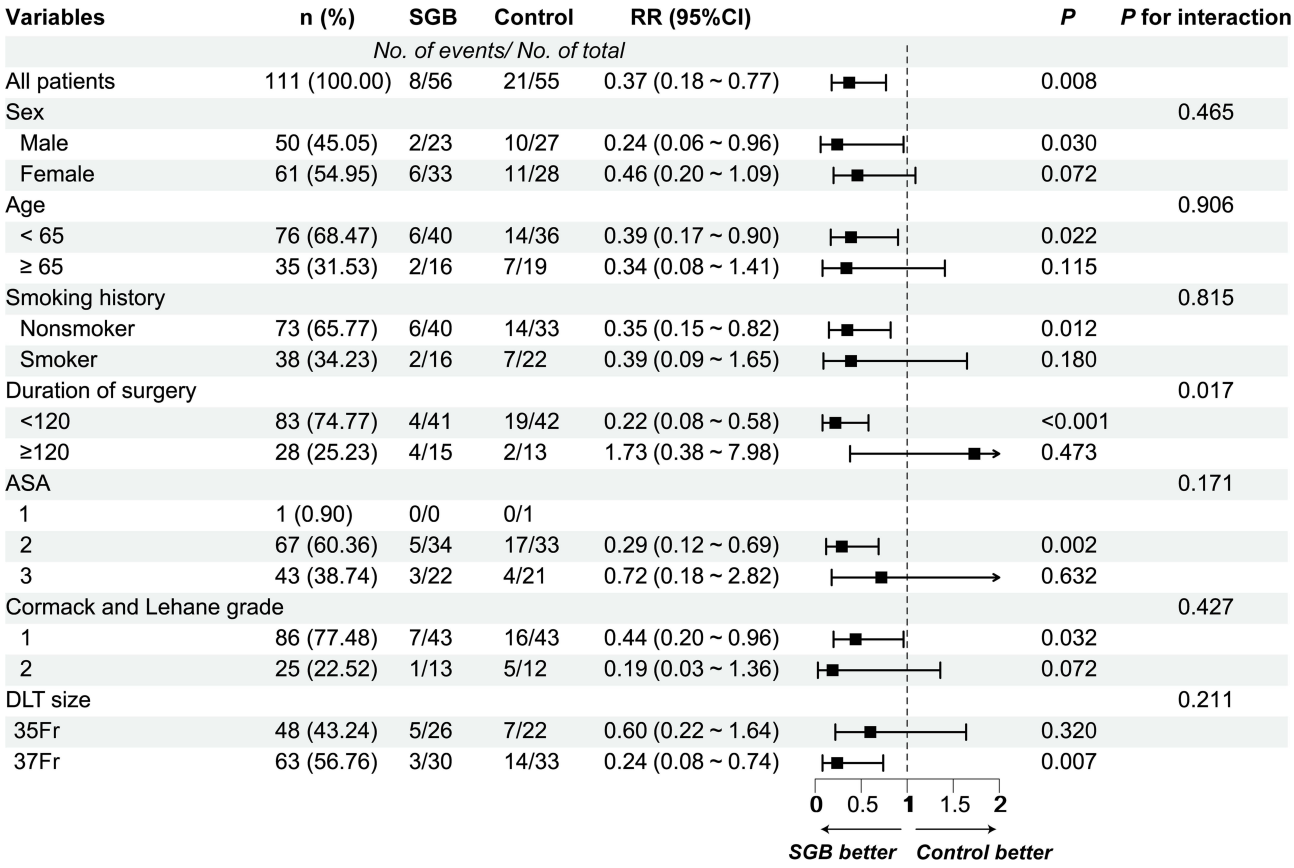

Figure 5 Subgroup analysis of incidence of POST at 6 h after surgery.
Abbreviations: ASA, American Society of Anesthesiologists; DLT, double-lumen endobronchial tube; POST, postoperative sore throat; SGB, stellate ganglion block; RR, relative risk.

intubation is primarily attributable to mechanical trauma-induced local inflammation.[3,41] Compared to single-lumen endotracheal tubes, DLTs possess a larger outer diameter and greater rigidity, and their placement necessitates repeated FB manipulation—collectively resulting in more pronounced mechanical injury to the pharyngeal mucosa, vocal folds,

Table 3 Safety Outcomes Within 24 h After Surgery

	SGB (n = 56)	Control (n = 55)	*P*-value
Hypotension*	16 (28.6)	14 (25.5)	0.712
Hypertension#	4 (7.1)	5 (9.1)	0.707
Bradycardia$	9 (16.1)	6 (10.9)	0.426
Tachycardia†	7 (12.5)	8 (14.5)	0.753
Desaturation‡	11 (19.6)	13 (23.6)	0.609
Local anesthetic systemic toxicity	0	0	>0.999
Hematoma	0	0	>0.999
Puncture-related infection	0	0	>0.999
Puncture-related Pneumothorax	0	0	>0.999
Recurrent laryngeal nerve block	3 (5.4)	0	0.177
Phrenic nerve block	0	0	>0.999
Brachial plexus block	0	0	>0.999

Notes: Data are number of patients (%). *Systolic BP <90 mmHg or >30% lower than baseline. # Systolic BP >180 mmHg or >30% higher than baseline. $HR <60 beats min^{-1} or >30% lower than baseline. †HR >100 beats min^{-1} or >30% higher than baseline. ‡Pulse oxygen saturation (breathing air) <90%.
Abbreviation: SGB, stellate ganglion block.

and tracheal mucosa.[18,42] Current strategies to mitigate POST encompass pharmacological interventions, non-pharmacological modalities, and diverse drug delivery routes; however, many pharmacologic agents are constrained by dose-limiting adverse effects.[2,3,43] Furthermore, despite various available preventive strategies, many patients still develop moderate to severe POST.[21,28,44] In our prior RCT, we found preoperative SLNB demonstrated efficacy in reducing POST incidence at 6 h after surgery, yet failed to sustain this protective effect beyond that timeframe—highlighting a critical gap in prolonged POST prevention.[28]

The 6-hour postoperative POST incidence in the control group was 38.2%, consistent with previous studies, confirming the 6-hour time point as the critical period for POST burden after DLT intubation. Notably, preoperative SGB reduced the POST incidence at 6 h after surgery to 14.3%, a finding that is largely consistent with our prior research. In our earlier study, preoperative SLNB was shown to decrease POST incidence from 41.5% to 17.1%;[28] similarly, Park et al[26] reported that the two-handed jaw thrust maneuver lowered POST incidence from 59% to 26%, and Chang et al[37] demonstrated that prophylactic administration of benzydamine hydrochloride reduced POST incidence from 56.5% to 23.9%. These collective data indicate that preoperative SGB yields a comparable protective effect against POST at 6 h after surgery to that of previously reported pharmacologic and nonpharmacologic prophylactic strategies. A key novel finding of the present study, however, is that SGB maintained a significant protective effect and reduced POST incidence at 24 h after surgery, which aligns with existing evidence supporting the efficacy of SGB in mitigating POST after tracheal intubation. Luo et al[33] reported that preoperative SGB significantly reduced the incidence and severity of POST after single-lumen tracheal tube intubation in patients undergoing lumbar surgery, yet this effect was restricted to 6 h after surgery. A plausible explanation for this discrepancy in treatment effect is that, in addition to the difference in LA used between the two studies, airway injury induced by DLT intubation in our study is more persistent and severe compared with that caused by single-lumen endotracheal intubation. Therefore, SGB may confer sustained protective benefits for patients undergoing DLT intubation.

As a well-established regional anesthetic technique, SGB has been shown to exert regulatory effects on sympathetic tone and anti-inflammatory actions, which are postulated to be the underlying mechanisms mediating its analgesic and anti-inflammatory efficacy in the upper airway.[45] In contrast, SLNB abrogates the conduction of pain signals rapidly by directly inhibiting sensory afferent fibers in the laryngopharyngeal mucosa, and its therapeutic effect is predominantly dependent on the pharmacodynamic duration of the LA administered.[28] In the present study, the protective effect of SGB persisted up to 24 hours postoperatively, whereas the pharmacodynamic duration of 0.5% ropivacaine is only approximately 6–8 hours. This prolonged effect suggests that the therapeutic benefits of SGB may extend beyond the intrinsic pharmacokinetic duration of the local anesthetic itself. This phenomenon can be explained by the dual sympathetic-modulating and anti-inflammatory effects of SGB. Clinically, SGB has been documented to decrease postoperative levels of IL-6, C-reactive protein (CRP), and norepinephrine.[31] Beyond this acute-phase suppression, preclinical evidence demonstrates that SGB also downregulates the IKK/NF-κB pathway and inhibits type 2 cytokines (IL-4, IL-5, IL-13),[45] highlighting its broader airway anti-inflammatory capacity that may provide additional protection in the context of thoracic surgery. Furthermore, SGB exhibits prominent regulatory effects on the sympathetic nervous system and maintained stable autonomic nervous function.[29,46]

In this study, SGB significantly lowered the incidence of 24-hour postoperative sleep disturbance, with marked improvements in anxiety and depression scores, consistent with the findings of Yang et al[30] in patients undergoing breast cancer surgery, suggesting that the sympathetic modulatory effects of SGB may disrupt the vicious cycle of "pain-sleep disturbance-emotional deterioration" by regulating the sleep-wake cycle and the function of the hypothalamic-pituitary-adrenal (HPA) axis.[47] Although the breast cancer population differs from our thoracic surgical cohort in important respects, the underlying mechanisms through which SGB improves sleep and emotional status are likely to be generalizable rather than disease-specific. These results indicate that SGB may confer broader perioperative benefits via central neural modulation. Preclinical studies have demonstrated that SGB can inhibit the release of norepinephrine (NE) from the locus coeruleus (LC) to key brain regions, thereby exerting a significant ameliorative effect on emotional and cognitive functions, and similar findings have been reported in several RCTs.[33,48–50] Furthermore, the regulatory effect of SGB on sympathetic balance has also been explored by our team as a potential therapy for chronic insomnia in the anesthesia clinic, although its efficacy for this indication remains investigational.[51]

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Subgroup analysis revealed a significant interaction between surgical duration and the therapeutic effect of SGB on POST, with patients undergoing surgery of less than 120 minutes deriving a more pronounced benefit from SGB. Previous studies have identified surgical duration as a significant risk factor for POST; prolonged surgery is associated with a longer indwelling time of the DLT, prolonged airway mucosal compression and a potentially higher frequency of FB adjustments, and the cumulative airway injury induced by these factors may exceed the protective capacity of SGB.[52–54] However, this interaction was identified in a prespecified, exploratory subgroup analysis that employed a $P < 0.10$ threshold for interaction significance, involved subgroups of unbalanced size, and was not adjusted for multiplicity. It should therefore be regarded as hypothesis-generating and requires independent validation in future studies specifically designed to test this hypothesis.[55]

In terms of safety outcomes, a relatively higher incidence of recurrent laryngeal nerve block was observed in the SGB group. As a known complication of SGB, recurrent laryngeal nerve block arises from the anatomical adjacency between the recurrent laryngeal nerve and the stellate ganglion: the recurrent laryngeal nerve courses along the tracheoesophageal groove and lies posterior to the carotid sheath, rendering it susceptible to infiltration by the spread of LA solution.[29] The incidence of recurrent laryngeal nerve block in the present study was 5.4%, and all cases were transient, resolving spontaneously within 24 hours without any severe associated complications being observed. However, in thoracic surgery patients—who depend on effective cough and intact glottic closure for secretion clearance and aspiration prevention in the immediate postoperative period—even transient unilateral vocal cord impairment warrants attention. Although no aspiration events or respiratory complications were observed in these patients, the risk–benefit balance of SGB for POST should nevertheless be carefully evaluated by the attending anesthesiologist.

Several limitations of this prospective RCT should be acknowledged when interpreting the study findings. First, the control group received 1% tetracaine gel for DLT lubrication; therefore, our study evaluated the incremental value of SGB added to routine practice rather than efficacy against a placebo. Second, although patients were formally blinded, some in the SGB group may have perceived the needle puncture or Horner's signs and inferred their allocation. The intubating anesthesiologist was also aware of group assignment due to the gel lubrication required in the control group, though this individual did not participate in outcome assessment. Coupled with our team's established interest in the neuropsychological applications of SGB—which may introduce unconscious investigator bias—these factors could collectively have influenced the subjective outcomes, even though all were assessed by blinded evaluators using prespecified instruments. Third, intention-to-treat analysis (ITT) was not performed, with some patients excluded per predefined intraoperative criteria. Fourth, this single-center, single-anesthesiologist design limits generalizability to settings with varying operator experience. Fifth, no upper age limit was applied at enrolment. Although a prespecified subgroup analysis found no evidence that age modified the treatment effect, a residual influence of age on baseline POST risk cannot be excluded; these warrants dedicated investigation in geriatric cohorts. Sixth, we did not measure inflammatory mediators, leaving the mechanistic basis of SGB's effects incompletely explored. Finally, Enhanced Recovery After Surgery (ERAS) protocol implementation led to a relatively short hospital stay, precluding assessment of the long-term prognosis of POST and its impact on patient quality of life.

Conclusion

This RCT suggests that preoperative ropivacaine-based SGB could reduce the incidence and severity of POST in thoracic surgery patients with DLT intubation, with a protective effect lasting at least 24 hours postoperatively. SGB could also improve postoperative sleep quality and emotional status. However, SGB did not significantly reduce hoarseness, and the risk of adverse effects warrant careful risk–benefit assessment. SGB may represent a new strategy for preventing POST, though these preliminary results require validation in larger multicenter studies.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

The study was conducted with Institutional Review Board approval from The Second Qilu Hospital of Shandong University in China (No: KYLL-2024-880) on October 31, 2024, and the guidelines outlined in the Declaration of Helsinki followed. The study protocol was registered in the Chinese Clinical Trial Registry (No: ChiCTR2400092313; date of registration: November 14, 2024) before the first patient enrollment. Written informed consent was obtained from all study participants.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; agreed on the journal to which the article has been submitted; and agreed to be accountable for all aspects of the work.

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Disclosure

No potential conflict of interest was reported by the authors.

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