Original Article

Single versus multisite intercostal nerve block for post-thoracoscopic pain: a prospective observational study

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Background: The analgesic efficacy of intercostal nerve block (ICNB) in adults undergoing thoracic surgery and the optimal extent of nerve block remain unclear. To evaluate the analgesic efficacy of ICNB and the optimal extent of nerve block in adults undergoing thoracoscopic surgery, we conducted a prospective cohort study of post-thoracoscopic pain.

Methods: We conducted a prospective observational cohort study to assess the postoperative pain intensity scores and other relevant factors associated with different ICNB techniques for pain management in thoracoscopic surgery in a tertiary hospital in Beijing, China. Postoperative pain management was categorized into three groups: the ICNB single-site injection (ICNB SI) group, in which the third to fifth intercostal nerves were blocked with 1 mL of 0.5% ropivacaine at each costal level; the ICNB incision-specific multi-site injection (ICNB ISMSI) group, in which the third to eighth intercostal nerves were blocked with 1 mL of 0.5% ropivacaine at each costal level; and the non-ICNB anesthesia group, which did not undergo any block.

Results: Pain intensity scores (visual analog scale, VAS) in the ICNB SI group were significantly lower than those in the ICNB ISMSI group within 24 hours after surgery (4.9±2.4 *vs.* 6.2±2.0). Within 24 hours after surgery (day 0), no significant difference in pain intensity scores was observed between the ICNB ISMSI group and the non-ICNB group (6.2±2.0 *vs.* 6.3±2.1). Additionally, ICNB was effective in reducing pain following thoracoscopic surgery, with analgesic effects lasting up to 4 days postoperatively. Long-term follow-up showed lower incidence of chronic chest pain and better quality of life (QL-Index) in the ICNB groups compared to the non-ICNB group (QL-Index scores: 9.18±0.7 at 3 months in the ICNB group *vs.* 8.67±0.5 in the non-ICNB group).

Conclusions: Thoracic incision-specific multi-site injections were not superior to single injections of ICNB in terms of post-thoracoscopic analgesia. The single-injection approach (ICNB SI) maintained analgesia for 4 days after thoracoscopic surgery, while the multisite injection (ICNB ISMSI) did not demonstrate this prolonged effect. Further research is needed to elucidate the exact mechanisms underlying these differential analgesic effects in clinical practice.

Keywords: Intercostal nerve block (ICNB); pain management; visual analog scale (VAS); thoracic surgery

Submitted Mar 27, 2025. Accepted for publication Apr 15, 2025. Published online Apr 22, 2025.
doi: 10.21037/jtd-2025-654
View this article at: https://dx.doi.org/10.21037/jtd-2025-654

Introduction

Postoperative pain following thoracic surgery remains a significant clinical challenge, with reported incidence rates ranging from 20% to 70% (1). Over the years, the understanding of pain has evolved, with the recognition that "Pain is not only a symptom but also a disease" being introduced at the 9th World Congress on Pain in Vienna in August 1999 (2). Uncontrolled pain in the early postoperative phase can negatively impact a patient's physiological functions, leading to complications such as myocardial ischemia or infarction, increased pulmonary risks such as infection and atelectasis, and prolonged hospital stays (3). Therefore, effective pain management in thoracic surgery is crucial (4).

Given that most related data have been derived from well-designed clinical trials involving carefully selected participants (5), we conducted this prospective observational cohort study to assess pain intensity scores and other relevant factors for postoperative pain management in thoracic surgery in different ICNB techniques among a Chinese population. We aimed to examine how variations in nerve block techniques—targeting different numbers of intercostal nerves and focusing on different anatomical regions—may affect pain outcomes. We hypothesized that the intercostal nerve block technique covering more nerve levels [ICNB incision-specific multi-site injection (ICNB ISMSI)] would provide better pain control compared to the single-level intercostal nerve block technique [single-site intercostal nerve block (ICNB SI)], given its broader coverage. We present this article in accordance with the TREND reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-2025-654/rc).

Highlight box

Key findings

- Single-site intercostal nerve block (ICNB SI) provides superior postoperative pain relief in thoracoscopic surgery compared to incision-specific multisite injection (ICNB ISMSI) and no ICNB treatment.
- No significant difference in pain intensity scores was observed between the ICNB ISMSI and non-ICNB groups within 24 hours after surgery.
- ICNB was effective in reducing pain following thoracoscopic surgery, with analgesic effects lasting up to 4 days postoperatively; ICNB SI was more effective than ICNB ISMSI.
- Long-term follow-up showed lower incidence of chronic chest pain and better quality of life in the ICNB groups as compared to the non-ICNB group.

What is known and what is new?

- ICNB is a commonly applied analgesic technique for thoracic surgery, known for its minimal impact on respiratory and circulatory systems as compared to thoracic epidural analgesia. Previous studies have shown that ICNB SI can provide effective pain relief within 24 hours after surgery.
- This study demonstrated that ICNB SI is more effective than is multisite injection for pain management in thoracoscopic surgery. Additionally, ICNB provides prolonged analgesic effects beyond the initial 24 hours, potentially reducing the incidence of chronic pain and improving long-term outcomes.

What is the implication, and what should change now?

- The findings indicate that ICNB SI may offer certain advantages in postoperative pain management for thoracoscopic surgery. However, due to the limitations of a non-randomized study design, it is not appropriate to conclude that it should be the preferred method. Further rigorous research, such as randomized controlled trials, would be necessary to establish causality and provide a stronger basis for clinical recommendations.

Methods

This study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. The China-Japan Friendship Hospital Ethics Committee granted ethical approval (No. 2023-KY-101) on July 16, 2023, for this real-world study. The study was a prospective open-label, nonrandomized real-world study performed in one medical center. Informed consent was obtained from the patients or legal representatives.

Study design

Consecutive patients were prospectively recruited from the Department of Thoracic Surgery at China-Japan Friendship Hospital between August and September 2023. The inclusion criteria were as follows: (I) age older than 18 years; (II) requirement for surgical treatment of small pulmonary nodules; (III) permanent residency status; (IV) availability

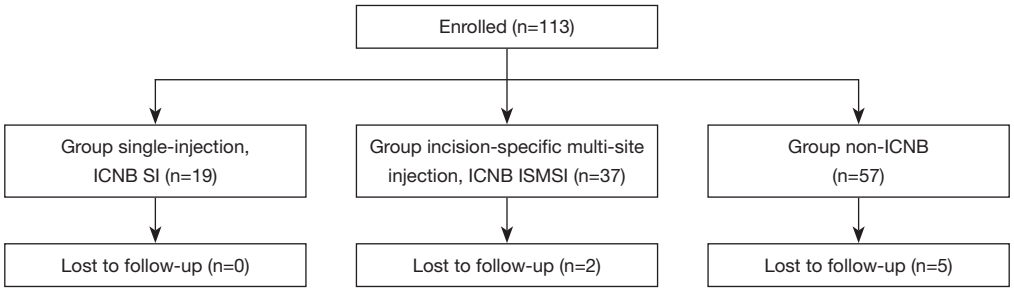

Figure 1 Flow diagram of patient inclusion. ICNB, intercostal nerve block; ISMSI, incision-specific multi-site injection; SI, single-site injection.

for long-term follow-up; and (V) written informed consent. Meanwhile, the exclusion criteria were as follows: (I) refusal to consent; (II) cardiovascular disease: presence of severe cardiovascular disease such as unstable angina, recent myocardial infarction (within the past 6 months), congestive heart failure, etc. Respiratory disease: pulmonary function tests suggestive of chronic obstructive pulmonary disease (COPD) grade II or higher [i.e., forced expiratory volume in 1 second (FEV_1)/forced vital capacity (FVC) <70% with or without FEV_1 <80% of predicted value].

Hepatic and renal dysfunction: Child-Pugh class C or estimated glomerular filtration rate (eGFR) <60 mL/min/1.73 m^2. (III) Contraindications to surgery (e.g., inability to tolerate anesthesia, distant metastasis, or bleeding tendencies); all patients had an incision between the fourth and seventh intercostal spaces. In the ICNB SI group (n=19), the third to fifth intercostal nerves were blocked with 1 mL of 0.5% ropivacaine at each costal level. In the ICNB ISMSI group (n=37): the third to eighth intercostal nerves were blocked with 1 mL of 0.5% ropivacaine at each costal level. In non-ICNB (n=57), no ICNB was performed. The distribution of patients into these groups is shown in *Figure 1*. Patients were assigned to the ICNB groups based on clinical decisions made by the surgical team. The choice between SI and ISMSI was influenced by factors such as the patient's specific condition, surgical requirements, and the surgeon's preference. This approach was chosen to reflect real-world clinical practice.

Interventions

A 10-mL syringe was loaded with 0.5% ropivacaine and connected to a 1-mL syringe needle through a pump tube. Air was removed from the system to ensure there were no air bubbles in the syringe. The injection was performed at the end of the procedure, just before the insertion of the thoracic drainage tube.

To block the intercostal nerves, the patient was positioned on their side, and the lung tissue was retracted forward to fully expose the lateral and posterior chest wall. Under thoracoscopic guidance, the intercostal nerves and their accompanying intercostal arteries were identified. The target intercostal nerve is located by the surgeon using a thoracoscope and a 1-mL syringe is guided with a thoracoscopic oval forceps. A single puncture of the parietal pleura, along the path of the intercostal nerve, was made. Under thoracoscopic guidance, we targeted the intercostal nerve at its angle of the rib, approximately 6–8 cm lateral to the paravertebral space (Figure S1). The injection was performed where the nerve lies between the internal intercostal membrane and pleura, before its division into collateral branches. In ICNB SI, 1 mL of 0.5% ropivacaine was injected into each of the third, fourth, and fifth intercostal nerves. In ICNB ISMSI, 1 mL of 0.5% ropivacaine was injected into each intercostal nerve from the third to the eighth intercostal space. The procedure was performed carefully to minimize the risk of systemic toxicity, and the patients' vital signs were monitored during and after the injections.

The non-ICNB group did not receive any nerve block, serving as the control group for the assessment of the impact of ICNB on pain management.

Assessments

Pain intensity was assessed using the visual analog scale (VAS) at various time points: within 24 hours after surgery (intervals: immediately after arrival in the ward, then at 2, 6, 12, and 24 hours) and on postoperative days 1, 2, 3, and 4. The VAS consists of a 10-cm line with anchor descriptors of "no pain" at 0 and "worst pain imaginable" at 10. Patients marked a point on the scale reflecting their perceived pain

level, and the distance from the left endpoint to the mark was measured.

The occurrence of persistent chest wall pain was assessed at 1, 3, and 6 months and 1 year after surgery. For the purposes of the study, persistent pain was defined as pain lasting more than 2 weeks after surgery and was based on patient reports during follow-up visits. For patients who reported persistent pain, the Quality of Life Index (QL-Index) and VAS scores were used to evaluate the impact of pain on daily life. Additionally, the frequency of intractable cough was recorded at the same follow-up points. Intractable cough was defined as a cough persisting for more than 3 weeks postoperatively despite standard treatments such as cough suppressants or supportive care. The QL-Index measures five dimensions of quality of life: activity, daily activities, general health, social support, and psychological outlook. Each item is rated on a scale from 0 (severe limitation) to 2 (no limitation), with a total score ranging from 0 to 10. A higher score indicates better quality of life.

Statistical analysis

Descriptive statistics were used to summarize demographic characteristics [age, gender, and body mass index (BMI)], clinical and surgical factors (operation duration, disease type, etc.), pain medication usage, and hospitalization data (intubation duration, discharge time, etc.) for all patients and by groups. Postoperative opioid consumption was calculated as morphine equivalent dose (MED) using standard conversions: 1 mg bucinnazine =0.33 mg morphine; 1 mg pethidine =0.11 mg morphine. MED reflected total postoperative opioid use during hospitalization.

Univariate analyses were first performed to assess the impact of different factors on pain levels (on postoperative days 0, 1, 2, 3, and 4). A multiple linear regression model was then constructed, including all significant variables from the univariate analysis. The final model, developed using a backward selection method, assessed the effect of ICNB on pain levels, with adjustments being made for confounding factors. After adjustments were made for the use of bucinnazine and/or pethidine, pathology, and MED, there was no significant difference in pain intensity between the ICNB ISMSI and non-ICNB groups (regression coefficient =–0.075; 95% CI: –0.891 to 0.741). However, the difference between the ICNB SI and non-ICNB groups remained statistically significant (regression coefficient =–1.224; 95% CI: –2.255 to –0.192). A P value <0.05 (two-tailed) was considered statistically significant. All statistical analyses were performed using R software version 4.2.0 (The R Foundation for Statistical Computing), and visualizations were created using GraphPad Prism version 9 (Dotmatics, Boston, MA, USA).

Results

Characteristics of patients

The patient, surgical, and postoperative characteristics are summarized in *Table 1*. Patients who underwent thoracoscopic surgery without ICNB anesthesia were slightly older compared to those who received ICNB (59.1 years in the non-ICNB group *vs.* 57.8 years in the ICNB SI group *vs.* 55.1 years in the ICNB ISMSI group). The proportion of patients diagnosed with cancer by postoperative pathology was 80.7% in the non-ICNB group, whereas this proportion was lower in the ICNB groups (63.2% in the ICNB SI group and 73.0% in the ICNB ISMSI group). The percentage of patients undergoing wedge resection was significantly lower in the non-ICNB group (36.8%) compared to the ICNB SI (57.9%) and ICNB ISMSI (51.4%) groups. No significant differences were observed between the groups in terms of gender distribution, BMI, or self-reported preoperative anxiety and depression scores.

The operation duration was longest in the ICNB ISMSI group (mean 133.4 minutes), followed by the non-ICNB group (mean 128.2 minutes), and shortest in the ICNB SI group (mean 115.3 minutes). A total of 33.6% of patients were administered bucinnazine and/or pethidine, with varying proportions across the treatment groups. The intubation duration was similar across all three groups.

Pain intensity after surgery

Within 24 hours after surgery (day 0), no significant difference in pain intensity (measured via the VAS) was observed between the ICNB ISMSI group and the non-ICNB group (6.2±2.0 *vs.* 6.3±2.1). The lowest pain intensity score was reported by patients in the ICNB SI group (4.9±2.4) (*Figure 2*).

For postoperative days 1 to 4, no significant difference in pain intensity was observed between the ICNB ISMSI group and the non-ICNB group (*Figure 3*). In contrast, the ICNB SI group consistently reported lower pain intensity

Table 1 Patient, surgical, and postoperative characteristics of thoracoscopic surgery with or without ICNB

Variable	With ICNB (n=56)		Without ICNB (n=57)
	SI (n=19)	ISMSI (n=37)	
Age, years	57.8±13.2	55.1±11.7	59.1±11.4
Male	8 (42.1)	17 (46.0)	26 (45.6)
BMI, kg/m^2	23.8±3.6	24.1±2.8	24.0±3.0
Pathology	12 (63.2)	27 (73.0)	46 (80.7)
Surgery type	11 (57.9)	19 (51.4)	21 (36.8)
Operation time, min	115.3±55.9	133.4±137.4	128.2±49.3
Anxiety	42.6±3.8	42.6±5.2	43.5±6.7
Depression	0.55±0.05	0.55±0.05	0.53±0.05
Bucinnazine/pethidine	6 (31.6)	14 (37.8)	18 (31.6)
MED[a], mg	36.1±4.65 (n=6)	28.6±28.4 (n=14)	34.6±17.7 (n=18)
Intubation length, days	3.6±1.5	3.6±1.3	3.7±1.7
Hospitalization length, days	5.1±1.8	4.4±1.4	4.9±2.1

Data are presented as mean ± SD or n (%). [a], 1 mg of bucinnazine can be converted to 1/3 mg morphine and 1 mg of pethidine to 1/9 mg of morphine (6). The pathology includes both malignant and benign conditions. BMI, body mass index; ICNB, intercostal nerve block; ISMSI, incision-specific multisite injection; MED, morphine equivalent dose; SI, single-site injection; SD, standard deviation.

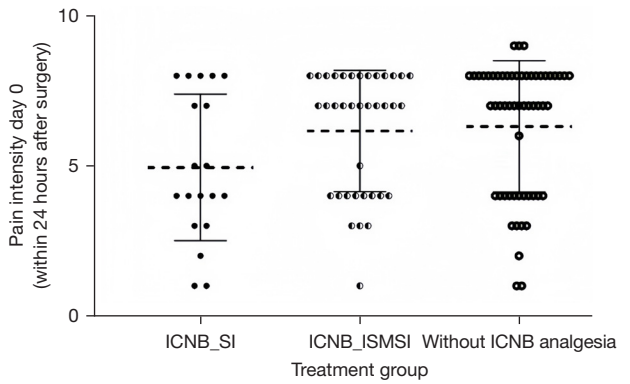

Figure 2 Pain intensity scores (0 to 10) within 24 hours (day 0) after surgery stratified by anesthetic approach. ICNB, intercostal nerve block; ISMSI, incision-specific multisite injection; SI, single-site injection.

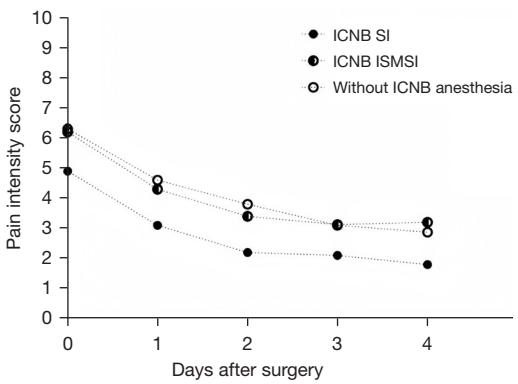

Figure 3 Pain intensity duration scores (0 to 10) from days 0–4 after surgery stratified by anesthetic approach. ICNB, intercostal nerve block; ISMSI, incision-specific multisite injection; SI, single-site injection.

scores over time (*Figure 3*).

Association of ICNB and self-reported pain intensity after surgery

Univariate analyses revealed that the factors significantly associated with pain intensity within 24 hours after surgery were ICNB SI (regression coefficient =–1.368; 95% CI: –2.512 to –0.224), malignant pathology (regression coefficient =1.234; 95% CI: 0.301–2.167), non-wedge surgery type (regression coefficient =0.886; 95% CI: 0.07–1.703), operation time (regression coefficient =0.005; 95% CI: 0.001–0.01), and MED (regression coefficient =0.047; 95% CI: 0.028–0.066) (*Table 2*).

Table 2 Association of ICNB and self-reported pain intensity scores (0 to 10) within 24 hours after surgery in the linear regression analyses (n=113)

Variable	Univariate analysis[a], β (95% CI)	Multivariate analysis[b], β (95% CI)
ICNB anesthesia		
Without	1.0 (referent)	1.0 (referent)
SI	−1.368 (−2.512, −0.224)	−1.224 (−2.255, −0.192)
ISMSI	−0.154 (−1.065, 0.758)	−0.075 (−0.891, 0.741)
Age (years)	−0.019 (−0.054, 0.016)	–
Gender		
Male	1.0 (referent)	–
Female	−0.078 (−0.912, 0.755)	–
BMI (kg/m^2)	0.118 (−0.018, 0.254)	–
Pathology		
Benign	1.0 (referent)	1.0 (referent)
Malignant	1.234 (0.301, 2.167)	0.950 (0.099, 1.801)
Surgery type		
Wedge	1.0 (referent)	–
Non-wedge	0.886 (0.07, 1.703)	–
Operation time (minutes)	0.005 (0.001, 0.01)	–
Anxiety (score)	0.012 (−0.06, 0.083)	–
Depression (score)	−1.157 (−9.041, 6.727)	–
Morphine equivalent dose (mg)	0.047 (0.028, 0.066)	0.046 (0.027, 0.064)
Intubation length (days)	−0.018 (−0.29, 0.255)	–
Hospital stay (days)	−0.018 (−0.241, 0.204)	–

[a], univariate analysis (without adjustment); [b], multivariate analysis (adjustment for significantly associated variables using backward selection method). –, not included; BMI, body mass index; CI, confidence interval; ICNB, intercostal nerve block; ISMSI, incision-specific multisite injection; SI, single-site injection.

After adjustments were made for potential confounding variables, multiple linear regression analyses were performed (*Table 2*). The final model with the backward selection method indicated that, after adjustments were made for the use of bucinnazine and/or pethidine and pathology, there was no significant difference in pain intensity between the ICNB ISMSI and non-ICNB groups (regression coefficient =−0.075; 95% CI: −0.891 to 0.741). However, the difference between the ICNB SI and non-ICNB groups remained statistically significant (regression coefficient =−1.224; 95% CI: −2.255 to −0.192). ICNB SI was found to significantly reduce postoperative pain. Further analysis revealed a significant correlation between increased postoperative pain scores and malignancy (regression coefficient =0.950; 95% CI: 0.099–1.801) (*Table 2*) and the dose of postoperative analgesics (regression coefficient =0.046; 95% CI: 0.027–0.064) (*Table 2*). Postoperative pain was not associated with surgery type (wedge resection *vs.* non-wedge resection) or surgery duration. No correlation was found with age, sex, BMI, length of chest drainage tube, or length of hospital stay. Additionally, no correlation was observed between preoperative anxiety or depression status and postoperative pain (*Table 2*). On postoperative day 1, ICNB SI was negatively correlated with pain intensity (regression coefficient =−1.406; 95% CI: −2.215 to −0.597). This negative correlation persisted through postoperative days 2 and 3, with regression coefficients of −1.407 (95% CI: −2.137 to −0.678) on day 2 and −0.862 (95% CI: −1.673

Table 3 Association of ICNB and self-reported pain intensity scores (0 to 10) during days 1 to 4 after surgery

Time section	Regression coefficient (95% CI)		
	With ICNB		Non-ICNB
	SI	ISMSI	
Day 1	−1.406 (−2.215, −0.597)	−0.297 (−0.950, 0.357)	1.0 (referent)
Day 2	−1.407 (−2.137, −0.678)	−0.273 (−0.867, 0.321)	1.0 (referent)
Day 3	−0.862 (−1.673, −0.051)	0.032 (−0.729, 0.665)	1.0 (referent)
Day 4	−0.747 (−1.811, 0.316)	0.331 (−0.504, 1.165)	1.0 (referent)

The number of patients included in the analyses for each treatment group on each day is as follows: Day 1: 111 patients (57 in the no block group, 19 in the single-site injection group, and 35 in the multiple-site injection group). Day 2: 94 patients (42 in the no block group, 18 in the single-site injection group, and 34 in the multiple-site injection group). Day 3: 53 patients (26 in the no block group, 11 in the single-site injection group, and 16 in the multiple-site injection group). Day 4: 30 patients (16 in the no block group, 5 in the single-site injection group, and 9 in the multiple-site injection group).

Table 4 Long-term follow-up results for patients who received thoracoscopic surgery with or without ICNB

Variable	With ICNB		Without ICNB (n=52)
	SI group (n=19)	ISMSI group (n=35)	
1 month after surgery			
Chronic chest pain	3 (15.8)	5 (14.3)	13 (25.0)
VAS*	1.67±0.6	1.40±0.5	3.46±1.1
QL Index*	10.0±0	9.80±0.4	8.38±0.7
Cough	5 (26.3)	14 (40.0)	16 (30.8)
3 months after surgery			
Chronic chest pain	2 (10.5)	6 (17.1)	9 (17.3)
VAS*	1.50±0.7	1.67±0.8	2.89±1.3
QL Index*	10.0±0	9.67±0.5	8.67±0.5
Cough	4 (21.1)	13 (37.1)	12 (23.1)

Data are presented as mean ± SD or n (%). *, results among patients with chronic chest wall pain. QL-Index was measured in all patients at 1 and 3 months. ICNB, intercostal nerve block; ISMSI, incision-specific multisite injection; SD, standard deviation; SI, single-site injection; VAS, visual analog scale; QL Index, Quality of Life Index.

to −0.051) on day 3 (*Table 3*).

Long-term follow-up results

The overall incidence of chronic chest pain was 19.8% at 1 month and 16.0% at 3 months. When stratified by treatment, the ICNB SI group showed the lowest incidence (1 month: 15.8% *vs.* ISMSI 14.3% *vs.* non-ICNB 25.0%; 3 months: 10.5% *vs.* 17.1% *vs.* 17.3%), with corresponding VAS scores consistently favoring ICNB SI (*Table 4*). The quality-of-life scores were 8.95±0.9 at 1 month and 9.18±0.7 at 3 months. The incidence of cough was 33.0% at 1 month and 27.4% at 3 months (*Table 4*).

Discussion

The primary aim of our study was to assess the effect of ISMSI ICNB compared to ICNB SI. We hypothesized that the multisite approach would provide superior analgesia via the targeting of more intercostal nerves in the vicinity of the incision; however, this was not confirmed by our results. We found that the analgesic effect of ICNB SI was

superior to that of the ISMSI. It was unclear why a single injection of local anesthetic at the intercostal nerve root was more effective than multiple injections at adjacent sites. One potential explanation is that this could be attributed to the targeted delivery of the anesthetic agent at specific intercostal nerve levels, which are most relevant to postoperative pain relief. This targeted approach may result in a more effective blockade compared to multiple injections that cover a broader area. Additionally, the single-injection approach may allow the anesthetic to act over a more extended period, potentially enhancing long-term pain relief. In conclusion, our findings suggest that while ISMSI may intuitively be the superior method for postoperative analgesia, it does not provide better pain relief as compared to ICNB SI in the context of thoracoscopic surgery. ICNB SI, performed carefully, appears to be the most effective approach for reducing postoperative pain, providing analgesia that lasts for at least 4 days after surgery. Additionally, the finding that ICNB SI reduces chronic pain and improves quality of life highlights its potential for long-term benefits in post-thoracoscopic surgery patients. This is particularly significant as chronic pain remains a challenging complication following thoracic surgery, impacting patient recovery and overall well-being. The mechanism by which ICNB SI may reduce chronic pain could be related to its effectiveness in minimizing acute postoperative pain, potentially preventing the transition from acute to chronic pain states. Additionally, the improved quality of life observed in the ICNB SI group underscores the importance of effective pain management in facilitating better functional outcomes and patient satisfaction. Future research should further investigate the long-term effects of ICNB SI on chronic pain and quality of life, as these outcomes are critical to enhancing postoperative recovery and patient-centered care.

Thoracic epidural analgesia (TEA) remains the gold standard for postoperative analgesia in thoracic surgery. However, it involves limitations, such as the lowering of blood pressure and the induction of cardiovascular events, including hypotension, bradycardia, and arrhythmias, which occur in up to 30% of cases (7-9). Although the incidence of minor side effects, such as perioperative hypotension, is lower with paravertebral block (PVB) compared to TEA, analgesic efficacy, major side effects (such as hematoma), and patient outcomes are considered comparable between TEA and PVB (10-14). A systematic review in 2021 showed that ICNB SI in thoracic surgery could effectively reduce pain within 24 hours after surgery, with clinical results being noninferior to those of PVB or TEA (15). However, the effectiveness of ICNB SI compared to multisite injection ICNB has not been fully examined, particularly in the context of postoperative pain relief following thoracoscopic surgery.

One possible explanation for the reduced efficacy of ISMSI in our study is the pain stimulation from the chest drainage tube, particularly from its continuous contact with the skin wound and parietal pleura. Although incision pain is effectively blocked by ICNB, irritation from the chest drainage tube is not fully alleviated. This could be due to the anatomical limitations of ICNB. ICNB primarily targets the ventral branches of the thoracic nerves, which are responsible for sensory innervation of the chest wall (16). However, the dorsal branches, which supply the paravertebral musculature and overlying skin and subcutaneous tissue, are not adequately blocked by this approach. As a result, pain conduction from the posterior and lateral chest wall remains unaddressed, particularly in areas affected by the chest drainage tube. The chest drainage tube is typically inserted in the mid-axillary line at the 4th to 7th intercostal space, which is outside the area covered by the ventral branches targeted by ICNB. This anatomical mismatch may explain why pain from the chest drainage tube is not fully alleviated by ICNB.

Another factor contributing to this phenomenon may be the difference in the intensity of pain stimuli. The local skin stimulation caused by the chest drainage tube, typically located at the upper chest cavity, is more intense than is the irritation caused by the parietal pleura or the incision site. The ICNB, which targets the sixth to ninth intercostal nerves, may not provide sufficient coverage of the areas affected by the chest drainage tube, particularly in the upper chest regions where the tube is typically inserted.

The injury and irritation of the intercostal nerves are major contributors to postoperative pain after thoracoscopic surgery. ICNB, when performed under direct thoracoscopic vision, can provide accurate, time-saving, and effective pain relief. This technique involves a precise injection of local anesthetic at the nerve root, with minimal disruption to surrounding tissues, such as the skin, subcutaneous fat, and muscle. Importantly, ICNB avoids the cardiovascular side effects associated with TEA, such as hypotension or hematoma, and has been shown to improve respiratory function by relieving chest wall pain, aiding recovery after thoracic surgery. It is important to note that chest drains are typically placed in the mid-axillary line at the 4th to 7th intercostal space, which is outside the area covered by

the intercostal nerves targeted by ICNB. This anatomical mismatch may explain why pain from the chest drainage tube is not fully alleviated by ICNB.

A previous study has suggested that the analgesic effects of ICNB are limited to the first 24 to 48 hours after surgery (16). However, in our study, after adjustments were made for potential confounding factors, the ICNB group experienced prolonged pain relief from postoperative days 1 to 4 even when the chest drainage tube and other interfering factors were removed. The reason for this extended analgesic effect could be related to the pharmacodynamics of the anesthetic used, particularly ropivacaine.

Ropivacaine is a long-acting amide local anesthetic that works primarily by blocking voltage-gated Na^+ channels in neuronal cell membranes, which prevents the conduction of nerve impulses responsible for pain signaling (17,18). Compared to bupivacaine, ropivacaine has a lower lipophilicity, fewer central nervous system and cardiac side effects, and a longer duration of action at similar concentrations (17-21). In addition to blocking sensory impulses, ropivacaine may also inhibit central nerve sensitization, reducing the transmission of pain signals to the central nervous system and preventing pain from being perceived by the brain (21-24). This could explain the prolonged analgesic effect observed in our study.

While the ICNB SI group maintained significantly lower pain scores throughout the 24-hour period (VAS 4.9±2.4), no significant difference was observed between the ICNB ISMSI (6.2±2.0) and non-ICNB (6.3±2.1) groups at any time point (P=0.87 for ISMSI *vs.* non-ICNB). This suggests that the local anesthetic delivered during ICNB may have an enduring effect on nerve membrane electrical activity, providing longer-term pain relief beyond the initial 24-hour period.

In our study, the incidence of chronic chest pain at 1 and 3 months after surgery was lower in the ICNB group than in the non-ICNB group. Additionally, patients who received ICNB reported better quality-of-life scores and lower pain scores at 3 months. These findings support the hypothesis that ICNB not only provides effective short-term pain relief but may also reduce the incidence of chronic pain by mitigating the overall stress response associated with surgery. By improving postoperative analgesia, ICNB may help prevent the development of chronic pain and improve long-term outcomes following minimally invasive thoracic surgery, such as video-assisted thoracic surgery.

Certain limitations to this study should be addressed. Given the prospective, observational nature of the study, patients were not randomly assigned to receive ICNB, and the decision to use ICNB was based on clinical needs and patient preference. This introduced the potential for selection bias, as patients who opted for ICNB might have had different pain tolerance levels or responses to anesthetic agents, which could have affected the pain assessments. Future randomized controlled trials are needed to eliminate these biases and provide more robust data. In addition, potential selection bias and confounding variables may affect study results. The lack of randomization means that factors affecting treatment selection (e.g., patient characteristics or surgeon preference) may not be evenly distributed across groups. Although we used statistical methods, such as multivariate regression and propensity score matching to adjust for known confounders, residual confounding due to unmeasured variables may still occur. Future studies with more robust study designs, such as randomized controlled trials, would help to further validate these findings and minimize the effects of selection bias and confounders. Additionally, the relatively small sample size in this study (37 in the ICNB ISMSI group, 19 in the ICNB SI group, and 57 in the non-ICNB group) limits the statistical power and external validity of our findings. We recognize that the small sample size, particularly in the ICNB SI group (n=19), limits the statistical power for certain subgroup analyses. This limitation affects the reliability and generalizability of the findings, especially when interpreting long-term outcomes. Small sample sizes can lead to wider confidence intervals and reduce the ability to detect statistically significant differences, even if clinically meaningful effects exist. Future studies with larger sample sizes are necessary to validate these findings and provide more robust evidence for the long-term benefits of ICNB SI. Another limitation is the reliance on the self-reported VAS to assess postoperative pain, which can be influenced by individual pain thresholds and subjective judgment. Future studies should consider incorporating additional objective pain assessments, such as physiological measures (e.g., heart rate and blood pressure) or clinician evaluations. Finally, the study did not fully account for all potential confounding factors, including postoperative complications, psychological factors (e.g., anxiety and depression), and individual patient characteristics. Future studies should aim to collect more comprehensive patient background data and adjust for these factors in the analysis to improve the accuracy of the findings.

Conclusions

This prospective observational study demonstrates that ICNB SI provides superior postoperative analgesia compared to multisite injection (ICNB ISMSI) and non-ICNB approaches in patients undergoing thoracoscopic surgery. The analgesic benefits of ICNB SI persisted for up to 4 days postoperatively, with lower pain intensity scores and reduced incidence of chronic chest pain at long-term follow-up. While ICNB ISMSI did not show significant advantages over no ICNB within the first 24 hours, both ICNB techniques were associated with improved quality of life compared to the non-ICNB group. These findings suggest that targeted SI nerve blockade may optimize pain management by delivering localized, prolonged analgesia while minimizing procedural complexity. However, the non-randomized design and small sample size limit the generalizability of these results. Future randomized controlled trials are necessary to validate these findings, elucidate mechanisms underlying prolonged analgesia, and establish standardized protocols for ICNB in thoracoscopic surgery. Clinically, ICNB SI should be considered a viable, effective option for enhancing postoperative recovery and reducing chronic pain risk in this patient population.

Acknowledgments

None.

Footnote

Reporting Checklist: The authors have completed the TREND reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-2025-654/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-2025-654/dss

Peer Review File: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-2025-654/prf

Funding: This study was supported by the "Elite Program" Talent Cultivation Project of China-Japan Friendship Hospital (No. ZRJY2021-GG02), the Special Funds for Clinical Operation Expenses of High-level Hospital of China-Japan Friendship Hospital (No. 2023-NHLHCRF-YYPPLC-ZR-04), and the Research and Translational Application of Capital Clinical Characteristic Diagnostic and Treatment Technology (No. Z211100002921007).

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-2025-654/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. Ethical approval was obtained from the China-Japan Friendship Hospital Ethics Committee (No. 2023-KY-101). Informed consent was obtained from the patients or legal representatives.

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Cite this article as: Wen B, Yao J, Wang S, Xu B, Zhang Y, Wang W, Xu Q, Li L, Liu C, Huang Y, Hanada S, Wang M, Shi Y, Zhang Z, Liang C, Zhang Y, Chen Y, Yang Y, Ma Q. Single versus multisite intercostal nerve block for post-thoracoscopic pain: a prospective observational study. J Thorac Dis 2025;17(4):2594-2604. doi: 10.21037/jtd-2025-654