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Original Article

# Ultrasound-Guided Erector Spinae Plane Block Versus Intercostal Nerve Block for Post-Minithoracotomy Acute Pain Management: A Randomized Controlled Trial

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*Objective:* Several nerve block procedures are available for post-thoracotomy pain management.
*Design:* In this randomized trial, the authors aimed to determine whether the analgesic effect of preoperative ultrasound-guided erector spinae plane block (ESPB) might be superior to that of intraoperative intercostal nerve block (ICNB) in pain control in patients undergoing minithoracotomy.
*Setting:* University hospital.
*Participants:* Sixty consecutive adult patients scheduled to undergo minithoracotomy for lung resection were enrolled.
*Interventions:* Patients were allocated randomly in a 1:1 ratio to receive either single-shot ESPB or ICNB.
*Measurements and Main Results:* The primary outcome was the intensity of postoperative pain at rest, assessed with the numeric rating scale (NRS). The secondary outcomes were (1) dynamic NRS values (during cough); (2) perioperative analgesic requirements; (3) patient satisfaction, on the basis of a verbal scale (Likert scale); and (4) respiratory muscle strength, considering the maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) variation from baseline. The ESPB group showed lower postoperative static and dynamic NRS values than the ICNB group ($p < 0.05$). Total remifentanil consumption and requirements for additional analgesics were lower in the ESPB group ($p < 0.05$). Patient satisfaction was higher in the ESPB group ($p < 0.001$). A significant overall time effect was found in MIP and MEP variation ($p < 0.001$); ESPB values were higher at all points, reaching a statistically significant level at the first and sixth hours for MIP, and at the first, 12th, 24th, and 48th hours for MEP ($p < 0.05$).
*Conclusions:* ESPB was demonstrated to provide superior analgesia, lower perioperative analgesic requirements, better patient satisfaction, and less respiratory muscle strength impairment than ICNB in patients undergoing minithoracotomy.
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*Key Words:* erector spinae plane block; intercostal nerve block; thoracic surgery; postoperative analgesia

Thoracotomy is considered one of the most painful types of surgical access.[1] Post-thoracotomy pain is attributable to several mechanisms, including muscle incisions, rib retraction or resection, intercostal nerve injury, and the presence of an indwelling chest tube. Inadequate pain management can lead to increased postoperative complications, especially in compromised patients.

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Acute pain may affect pulmonary function and clearance of secretions. Thus, postoperative pain control is crucial in decreasing morbidity and mortality after major thoracic surgery.[2] Numerous analgesic techniques are available for the management of acute post-thoracotomy pain, including patient-controlled analgesia, regional nerve blockades, and neuraxial blocks. Thoracic epidural analgesia (TEA) and thoracic paravertebral block (TPVB) are currently the recommended techniques for managing post-thoracotomy pain.[3] However, both TEA and TPVB have high failure rates (15%).[4] TPVB can cause complications such as pneumothorax or neuro-axial injury, owing to its proximity to important structures such as the pleura and spinal cord.[5] Although TEA long has been considered the gold standard in postoperative pain management, increasing evidence suggests that less invasive peripheral analgesic techniques are equally effective in pain management.[6] Regional blocks also contribute to reducing opioid use and related adverse effects, such as respiratory depression, sedation, nausea, and vomiting.[7] Peripheral techniques are also preferable because of their unilateral nature and reduced rates of complications, such as epidural hematoma and extensive sympathetic block.[8] If both TEA and TPVB are contraindicated or not feasible, intercostal nerve block (ICNB) is currently the only other recommended regional anesthesia technique beyond systemic analgesia.[9,10] Because of its simplicity, ICNB is one of the most frequently used techniques for post-thoracotomy analgesia.[11-13] This block also represents the standard treatment for pain management in the authors' institution after thoracic surgery. The erector spinae plane block (ESPB), a novel interfascial block first described in 2016 for thoracic neuropathic pain treatment,[14] recently has been shown to be a simple and safe alternative analgesic technique for acute postsurgical thoracic pain.[4,15-29] However, to date, ESPB has been described only in case reports, and few trials have investigated its efficacy.

This prospective randomized clinical trial with 60 patients undergoing minithoracotomy for lung surgery aimed to determine whether the analgesic effect of ESPB might be superior to that of ICNB in pain control. The measured primary outcome was the postoperative numeric rating scale (NRS) for pain at rest after surgery. The secondary endpoints were NRS values during cough and the amount of additional analgesic drug requested by the patients at 1, 6, 12, 24, and 48 hours after extubation; the amount of remifentanil infused during the surgical procedure; patient satisfaction with the analgesic technique, assessed on a verbal detection satisfaction scale (Likert scale); and comparison of the respiratory muscle strength, on the basis of postoperative maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) variation in both groups relative to the preoperative baseline values.

## Methods

This prospective, randomized, single-center, single-blinded controlled study was approved by the Bioethics Committee of Sapienza University of Rome (No. 5303_2019) and registered at www.clinicaltrials.gov (NCT04013815). Written informed consent was obtained from each patient before enrollment. From July to October 2019, 60 consecutive patients scheduled for elective lobectomy or wedge resection via minithoracotomy were included in the study. The Consolidated Standards of Reporting Trials flow diagram was used for enrollment and allocation of patients (Fig 1).

### *Study Design and Patients*

Upon ward admission, patients were allocated to the ESPB group or ICNB group according to a computer-generated random

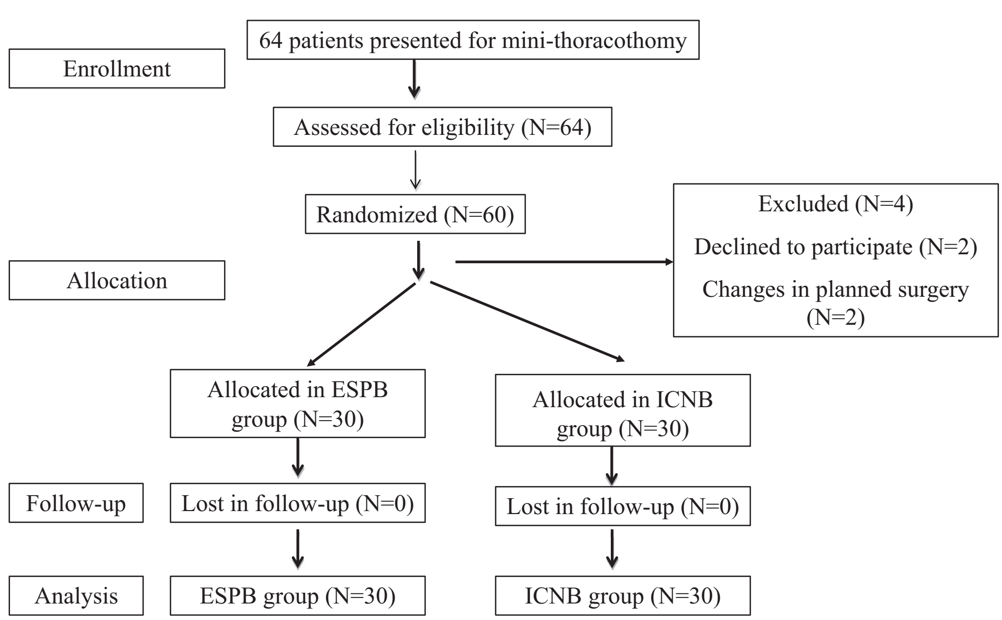


Fig 1. Study flowchart. ESPB, erector spinae plane block; ICNB, intrapleural intercostal nerve block.

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number table. Group allocation was concealed by sequentially numbered, sealed opaque envelopes, which were opened before the procedure in the operating room. The investigator (C.M.) performing the randomization did not play any role in the collection of postoperative data or its analysis.

Exclusion criteria were emergency surgery, pregnancy, patient refusal or inability to give consent, allergy or contraindication to the use of any of the study drugs, age ≤18 years, American Society of Anesthesiologists class ≥IV, intraoperative rib fractures, and preoperative chronic or neuropathic pain.

### *Technique*

Before surgery, patients received premedication with 0.03 mg/kg of midazolam, 8 mg of ondansetron, 30 mg of ketorolac tromethamine, 4 mg of dexamethasone, and 40 mg of pantoprazole intravenously. Anesthesia was induced intravenously with 1.5 to 2 mg/kg of propofol, 2 μg/kg of fentanyl, and 0.3 mg/kg of ketamine. Orotracheal intubation was performed with a double-lumen endobronchial tube after administration of 0.6 mg/kg of rocuronium bromide. The correct positioning of the double-lumen endobronchial tube was evaluated by fiberoptic bronchoscopy after endobronchial intubation and then after the patients were positioned in lateral decubitus. Maintenance of general anesthesia was achieved with desflurane (1 minimum alveolar concentration) and continuous infusion of remifentanil, with a target-controlled infusion system in effect-site target mode with an Alaris PK syringe pump. The target effect-site concentration of remifentanil was calculated with a Minto pharmacokinetic set. Ventilation was performed in volume-controlled mode with a tidal volume of 4 to 6 mL/kg, 5 $cmH_2O$ positive end-expiratory pressure, fraction of inspired oxygen of 0.5, 1:2 inspiratory-expiratory ratio, and a respiratory rate of 12 to 18 breaths/min, to maintain an end-tidal concentration of $CO_2 < 40$ mmHg. Intraoperative monitoring included a 5-lead electrocardiogram, invasive blood pressure continuously recorded via an arterial line, oxygen saturation by pulse oximetry, and expired $CO_2$. The surgical approach in all patients was a muscle-sparing minithoracotomy through the fifth intercostal space, usually extended from the posterior to the anterior axillary line for a length ranging between 10 and 13 cm, with limited rib retraction applied. The chest tube exits were infiltrated with 10 mL of ropivacaine 0.5%. All patients received a 24-hour intravenous continuous infusion of 0.1 mg/kg/h of tramadol and 90 mg of ketorolac with an elastomeric pump (2 mL/h). At the end of the surgical procedure, patients were extubated and transferred to the recovery room. Postoperatively, the severity of pain was assessed with the NRS at 1, 6, 12, 24, and 48 hours after surgery. The NRS was recorded as static (during normal breathing) and dynamic (during voluntary cough) measurements. All patients received 1 g of paracetamol intravenously as rescue analgesia if the NRS score at rest was greater than 3 or the patient demanded additional analgesia. Respiratory muscle strength was assessed with respiratory pressure tests recorded with a handheld electronic pressure transducer (CareFusion MicroRPM, Chatham, UK). Measurements were performed on patients in a semi-sitting position in bed. Both the MIP and the MEP were recorded before surgery and at 1, 6, 12, 24, and 48 hours after extubation. A pain management anesthesiologist (G.L.) blinded to the study groups was responsible for postoperative follow-up.

### *Ultrasound-Guided ESPB*

Before general anesthesia induction, ultrasound-guided ESPB was performed deep in the erector spinae muscle in patients placed in sitting position, with a high-frequency (12 MHz) linear transducer (M7, Mindray Medical International Co. Ltd., Shenzhen, China) (Fig 2). The tip of the T5 transverse process and the erector spinae muscle were identified in longitudinal parasagittal orientation 3 cm lateral to the midline. With aseptic technique, a 50-mm 22-gauge block needle (Arrow UltraQuik Echogenic PNB Needle, Teleflex Medical, Markham, Ontario, Canada) was inserted in-plane to the ultrasound beam in the cranial-to-caudal direction to contact the tip of the transverse process. After the correct location of the needle tip was confirmed by injection of 3 mL of saline, 20 mL of 0.75% ropivacaine was injected into the interfascial plane between the erector spinae muscle and transverse process (Fig 3). Injection of local anesthetic resulted in an extensive linear spread of local anesthetic lifting the erector spinae muscle. All erector spinae plane blocks were performed by the same 2 anesthesiologists (S.F., D.M.), both with experience in ultrasound-guided nerve blocks. The ESPB execution time did not exceed 10 minutes in all cases.

Fig 2. Erector spinae plane block performed under aseptic conditions at the T5 vertebral level with in-plane technique.

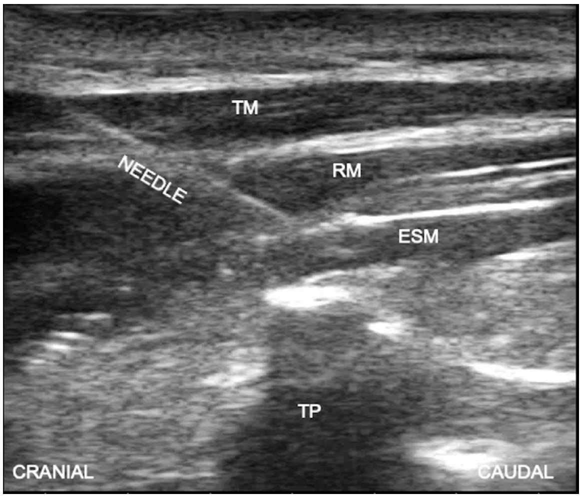


Fig 3. Sonographic anatomy and needle direction during erector spinae plane block performance. ESM, erector spinae muscle; RM, rhomboid muscle; TM, trapezius muscle; TP, transverse process.

### Intrapleural ICNB

Patients received ICNB from the fourth to the eighth space, as performed by the surgeon at the moment of thoracotomy under direct vision from inside the chest, with 20 mL of 0.75% ropivacaine, 4 mL for each space (Fig 4). Injection of the local anesthetic in each intercostal space was performed approximately 2 to 3 cm from the spine. All intercostal nerve blocks were performed by the same 2 thoracic surgeons (M.I., E.A.R.), both with experience in this technique.

### Efficacy Measures

The primary endpoint was pain at rest on the basis of the NRS score. The secondary endpoints were dynamic NRS values (during cough) and the amount of additional analgesic drug requested by the patient at 1, 6, 12, 24, and 48 hours after extubation; the evaluation of the amount of remifentanil infused during the surgical procedure; postoperative MIP and MEP variation in both groups regarding the preoperative baseline value (T0); and patient satisfaction with the analgesic technique on a 5-point verbal detection satisfaction scale (Likert scale: very satisfied [5], satisfied [4], neither satisfied nor dissatisfied [3], dissatisfied [2], and very dissatisfied [1] from highest to lowest). This scale has been used to assess patient satisfaction with perioperative anesthetic management.[30]

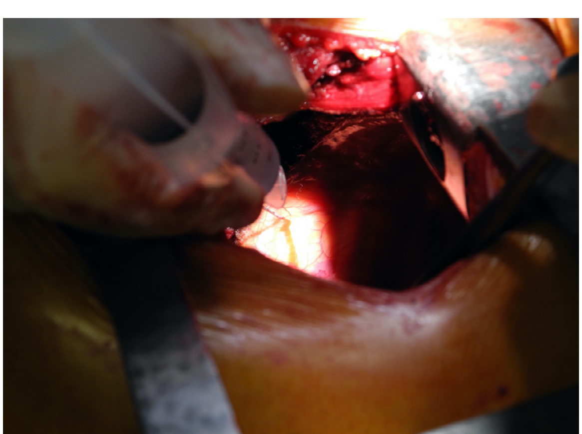

Fig 4. Intrapleural intercostal nerve block performed by surgeon.

### Statistical Analysis

The calculation of the sample size was carried out according to an assumption based on previous data,[12] in which, when the intrapleural intercostal block was performed, the postoperative mean NRS score during 48 hours after surgery was $1.72 \pm 0.7$. On the basis of the assumption that a 35% variation in the NRS was significant, the authors required 27 patients for each group to achieve a statistical power of 85% ($\alpha = 0.05$, $\beta = 0.15$). Considering 15% possible dropouts, 64 patients were enrolled in the study. The Shapiro-Wilk test was used to assess the normality of distributions. Mean values and standard deviation were determined with Student's *t* test for each quantitative variable. The Fisher exact test was applied for qualitative variables. The Mann-Whitney U-test was used when the distribution was non-normal. Repeated-measures analysis of variance with post hoc Bonferroni correction also was performed to compare the summary mean NRS score at rest and during cough.

For each group, the changes in MIP and MEP values over time from the preoperative baseline value (T0) to 1, 6, 12, 24, and 48 hours after surgery were analyzed with a repeated-measures analysis of variance with post hoc Bonferroni correction to assess an overall time effect, and values at different points (T0 to 1 hour, 1 to 6 hours, 6 to 12 hours, 12 to 24 to 48 hours, and T0 to 48 hours) were compared with paired *t* tests. p values $<0.05$ were considered significant. Data were analyzed in SPSS Statistics version 25.0 (SPSS Inc., Chicago, IL).

## Results

The present study included 60 patients who were assigned in a 1:1 ratio to receive either single-shot ultrasound-guided ESPB or ICNB, as shown in Figure 1. There were no statistically significant differences in the demographic or clinical data between the 2 groups, as illustrated in Table 1. Regarding the primary outcomes, the ESPB group showed significantly lower static and dynamic NRS values than the ICNB group throughout the study duration as shown in Table 2. Perioperative data for the ESPB group and the ICNB group are shown in Table 3. Patient satisfaction with the analgesic method, as expressed on a Likert scale, was significantly greater in the ESPB group than the ICNB group ($4.77 \pm 0.43$ *v* $4.05 \pm 0.92$, respectively; $p < 0.01$). Postoperative total additional analgesic drug requests were lower in the ESPB group than the ICNB group throughout the study duration as shown in Table 4. No complications were associated with the peripheral analgesia technique used, and no anesthetic toxicity signs owing to local anesthetic reabsorption were reported in either group.

The preoperative MIP and MEP values compared with those at 1, 6, 12, 24, and 48 hours after surgery are shown in Table 5.

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Table 1
Demographic and Epidemiological Data in the Overall Population, the ESPB Group, and the ICNB Group

| Parameter | All (N = 60) | ESPB (N = 30) | ICNB (N = 30) | p Value |
|---|---|---|---|---|
| Sex (M/F) | 32/28 | 18/12 | 14/16 | 0.438 |
| Age (y) | 67.92 ± 10.60 | 67.47 ± 9.34 | 68.37 ± 11.88 | 0.746 |
| BMI (kg/m$^2$) | 25.44 ± 4.10 | 25.32 ± 4.24 | 25.57 ± 4.01 | 0.813 |
| ASA (II/III) | 25/35 | 11/19 | 14/16 | 0.601 |
| $FEV_1$ (% predicted) | 92.21 ± 27.12 | 88.64 ± 22.63 | 95.79 ± 31.10 | 0.326 |
| Comorbidity | | | | |
| CAD | 8/60 | 3/30 | 5/30 | 0.706 |
| COPD | 16/60 | 7/30 | 9/30 | 0.771 |
| Diabetes mellitus | 8/60 | 3/30 | 5/30 | 0.706 |
| Hypertension | 35/60 | 19/30 | 16/30 | 0.601 |
| Scheduled surgery | | | | |
| Right lobectomy | 21 | 10 | 11 | 1.000 |
| Left lobectomy | 13 | 6 | 7 | 1.000 |
| Right wedge resection | 13 | 7 | 6 | 1.000 |
| Left wedge resection | 13 | 6 | 7 | 1.000 |
| Pathology | | | | |
| Squamous | 32 | 14 | 18 | 0.437 |
| Adeno | 4 | 3 | 1 | 0.612 |
| Metastasis | 9 | 5 | 4 | 1.000 |
| Other | 15 | 8 | 7 | 1.000 |

NOTE. The data are expressed as mean ± SD or N° of patients
Abbreviations: Adeno, adenocarcinoma; ASA, American Society of Anesthesiologists; BMI, body mass index; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; ESPB, erector spinae plane block; F, female; $FEV_1$, forced expiratory volume in 1 s; ICNB, intercostal nerve block; M, male; SD, standard deviation; Squamous, squamous cell carcinoma.

Table 2
Summary Mean NRS and NRS Values at 1, 6, 12, 24, and 48 h After Surgery at Rest and During Cough for the ESPB Group and ICNB Group

| NRS Values | ESPB (n = 30) | ICNB (n = 30) | Mean Difference (95% CI) | p Value |
|---|---|---|---|---|
| NRS at rest 1 h | 0.31 ± 0.80 | 3.03 ± 2.55 | 2.72 (1.72-3.72) | <0.001 |
| NRS during cough 1 h | 0.48 ± 1.09 | 4.00 ± 3.19 | 3.51 (2.26-4.77) | <0.001 |
| NRS at rest 6 h | 0.68 ± 1.24 | 3.20 ± 2.91 | 2.52 (1.30-3.73) | <0.001 |
| NRS during cough 6 h | 1.14 ±.77 | 4.44 ± 3.121 | 3.29 (1.91-4.68) | <0.001 |
| NRS at rest 12 h | 0.45 ± 1.05 | 2.84 ± 2.34 | 2.39 (1.42-3.36) | <0.001 |
| NRS during cough 12 h | 1.48 ± 2.13 | 5.08 ± 2.46 | 3.59 (2.34-4.85) | <0.001 |
| NRS at rest 24 h | 0.52 ± 1.18 | 2.23 ± 2.56 | 1.71 (0.61-2.80) | 0.003 |
| NRS during cough 24 h | 2.00 ± 2.33 | 5.15 ± 2.70 | 3.15 (1.76-4.54) | <0.001 |
| NRS at rest 48 h | 0.8 ± 1.55 | 2.17 ± 2.66 | 1.28 (0.01-2.54) | 0.041 |
| NRS during cough 48 h | 2.73 ± 1.99 | 4.46 ± 3.00 | 1.72 (0.28-3.16) | 0.020 |
| Mean NRS at rest | 0.91 ± 0.13 | 2.70 ± 0.23 | 2.13 (1.20-3.06) | <0.001 |
| Mean NRS during cough | 1.54 ± 0.172 | 4.64 ± 0.26 | 2.67 (1.51-3.84) | <0.001 |

NOTE. The data are expressed as mean ± SD (95% CI).
Abbreviations: ESPB, erector spinae plane block; ICNB, intercostal nerve block; NRS, numeric rating scale; SD, standard deviation.

According to the analysis of variance comparing MIP and MEP values between groups, a significant overall time effect was found ($F = 24.91$ and $F = 38.02$, respectively, $p < 0.001$). Respiratory muscle strength was better preserved in ESPB patients. In both groups, the MIP and MEP values decreased at the first hour postoperatively and then gradually increased, as illustrated in Figures 5 and 6.

## Discussion

Peripheral nerve block procedures have been demonstrated to be effective for the management of acute post-thoracotomy pain. However, to the authors' knowledge, this is the first randomized controlled trial to compare postoperative analgesia between ICNB and ESPB after minithoracotomy. The present study showed that the ESPB technique led to statistically significant lower postoperative pain scores than the ICNB technique. In addition, the patients in the ESPB group needed lower doses of supplemental analgesic drugs and had lower consumption of intraoperative remifentanil; they also showed better satisfaction with the analgesic technique. Although the ESPB group showed a reduced analgesic request during the perioperative period, it is important to underline that additional analgesic consumption was ultimately low in both groups. Even if ICNB was performed by the surgeon at the moment of thoracotomy, the preoperative execution of ESPB may have produced a longer-acting and better postoperative analgesic effect owing to a pre-emptive analgesia that reduced pain sensitization. Moreover, a before-surgery nerve block may account for the lower consumption of remifentanil and may have prevented opioid-induced hyperalgesia.

In post-thoracic surgery pain management, ESPB is performed in the posterior thoracic region homolateral to the site of the intervention at the level of the T5 transverse process, representing the ultrasound marker of the block. The erector spinae plane block is easy and safe to perform because of the ultrasound-guided method and the absence of vascular and nervous structures near the injection site. A T5-level block provides analgesia of both the anterolateral thoracic wall and axillary region. Cadaveric studies[14] have shown the spreading of anesthetics in the cranial-caudal sense (C7-T8), along the fascia between the erector spinae and large rhomboid, and in the anteroposterior sense, with block of the thoracic spinal nerve roots when ESPB is performed at the T5 level with 20 mL of anesthetic injected. The distribution of the local anesthetic showed to be similar between ESPB and TPVB: it diffuses anteriorly into the adjacent paravertebral and intercostal spaces, potentially blocking not only the ventral and dorsal rami of spinal nerves but also the rami communicantes containing sympathetic fibers.[31] Conversely, during ICNB, the local anesthetic agent primarily spreads into intercostal spaces.[32] This different distribution of local anesthetic may contribute to explaining the better analgesia that ESPB provided in this study.

At present, the literature concerning ESPB use in thoracic surgery is limited to case reports, editorials, and a few clinical trials.[4-5,22-29] The ESPB has been shown to be an effective

Table 3
Perioperative Data for the ESPB Group and ICNB Group

| Perioperative Data | ESPB (n = 30) | ICNB (n = 30) | Mean Difference (95% CI) | p Value |
|---|---|---|---|---|
| Anesthesia duration (min) | 95.47 ± 21.99 | 84.33 ± 24.61 | −11.13 (−23.21 to 0.94) | 0.070 |
| Remifentanil total (μg) | 216.54 ± 102.62 | 341.39 ± 158.18 | 124.85 (53.41-196.29) | 0.001 |
| Remifentanil (μg/kg/min) | 0.03 ± 0.018 | 0.05 ± 0.021 | 0.02 (0.01-0.03) | 0.001 |
| Length of stay (d) | 6.03 ± 4.64 | 5.10 ± 2.18 | 0.93 (−2.80 to 0.94) | 0.323 |
| Drainages, n° | 1.37 ± 0.49 | 1.50 ± 0.50 | 0.13 (−0.12 to 0.39) | 0.142 |
| Postoperative complications | | | | |
| Arrhythmic (atrial fibrillation) | 1/30 | 1/30 | | 1.000 |
| Respiratory failure | 0/30 | 0/30 | | |
| Pneumonia | 0/30 | 0/30 | | |

NOTE. The data are expressed as mean ± SD (95% CI).
Abbreviations: ESPB, erector spinae plane block; ICNB, intercostal nerve block; SD, standard deviation.

Table 4
Additional Analgesic Drug Requests in the ESPB Group and ICNB Group at 1, 6, 12, 24, and 48 h After Surgery

| Additional Analgesic Drugs | ESPB (n = 30) | ICNB (n = 30) | Mean Difference (95% CI) | p Value |
|---|---|---|---|---|
| Total additional analgesic drugs, n° | 1.0 ± 1.5 | 2.41 ± 1.99 | 1.37 (0.44-2.31) | 0.047 |
| Additional analgesic drugs at 1 h, n° | 0 ± 0 | 0.34 ± 0.55 | 0.34 (0.13-0.55) | 0.001 |
| Additional analgesic drugs at 6 h, n° | 0.08 ± 0.27 | 0.36 ± 0.56 | 0.28 (0.03-0.53) | 0.027 |
| Additional analgesic drugs at 12 h, n° | 0.45 ± 0.78 | 0.87 ± 0.81 | 0.42 (−0.02 to 0.86) | 0.064 |
| Additional analgesic drugs at 24 h, n° | 0.37 ± 0.56 | 0.62 ± 0.57 | 0.24 (−0.06 to 0.55) | 0.123 |
| Additional analgesic drugs at 48 h, n° | 0.19 ± 0.4 | 0.58 ± 0.88 | 0.39 (0.07-0.77) | 0.046 |

NOTE. The data are expressed as mean ± SD (95% CI).
Abbreviations: ESPB, erector spinae plane block; ICNB, intercostal nerve block; SD, standard deviation.

Table 5
Summary Table of Preop at 1, 6, 12, 24, and 48 h Postoperative MIP and MEP Values, and Percentage of Loss From Baseline (Δ%)

| | Group | Preop | 1 h | 6 h | 12 h | 24 h | 48 h | Δ% |
|---|---|---|---|---|---|---|---|---|
| MIP, $cmH_2O$ | ESPB | 53.60 ± 24.06 | 27.84 ± 17.06*,† | 32.12 ± 15.61*,† | 34.15 ± 17.56 | 33.93 ± 18.43 | 35.08 ± 14.11 | 34‡ |
| | ICNB | 47.23 ± 22.963 | 16.25 ± 8.91* | 23.63 ± 11.95* | 29.80 ± 14.58* | 32.77 ± 9.63 | 32.50 ± 13.88 | 31‡ |
| MEP, $cmH_2O$ | ESPB | 68.53 ± 16.97 | 37.08 ± 18.54*,† | 42.32 ± 15.45* | 47.59 ± 15.19† | 47.52 ± 14.55† | 58.63 ± 13.91*,† | 14‡ |
| | ICNB | 59.53 ± 20.12 | 27.04 ± 10.43* | 37.46 ± 16.62 | 37.83 ± 10.63 | 39.00 ± 11.76 | 40.56 ± 12.51 | 32‡ |

NOTE. Values are presented as mean ± SD and percentage.
Abbreviations: ESPB, erector spinae plane block; ICNB, intercostal nerve block; MEP, maximal expiratory pressure; MIP, maximal inspiratory pressure; Preop, preoperative; SD, standard deviation.
* $p < 0.05$, compared with previous test.
† $p < 0.05$, ESPB compared with ICNB.
‡ $p < 0.05$, preoperative compared with 48 h postoperative; Δ%, % change preoperative to 48 h postoperative.

peripheral technique for postoperative pain management in this group of patients. In agreement with these reports, the results of the present study proved that ESPB provided adequate analgesia after minithoracotomy: the average static and dynamic NRS scores did not exceed 3 in the entire follow-up period, and requests for additional analgesic drugs were low.

Compared with TEA and TPVB, ESPB appears to be safer and to pose a minimal risk of pleural puncture and epidural spread.[4] In addition, coagulopathy should not be a contraindication, given that the procedure is performed at distance from the spinal cord or the epidural venous plexus, thereby avoiding the risk of epidural hematoma.[24] ICNB is performed just below a rib in the region of the intercostal bundle, under direct vision by the surgeon after thoracotomy, and intravascular injection of the dose is avoided.[13] Because local anesthetic near the intercostal nerve covers a specific dermatomal area, multiple injections are needed for analgesia of the homolateral thoracic wall.[33] Although systemic toxicity is rare, ICNB can be associated with a higher risk of high uptake of local anesthetics because of increased vascularity in this region.[34]

In thoracoscopic surgery, ultrasound-guided ICNB and single-injection ESPB both have been demonstrated to provide inferior analgesia to multiple-injection TPVB, whereas no difference in postoperative analgesic effects has been found between ICNB

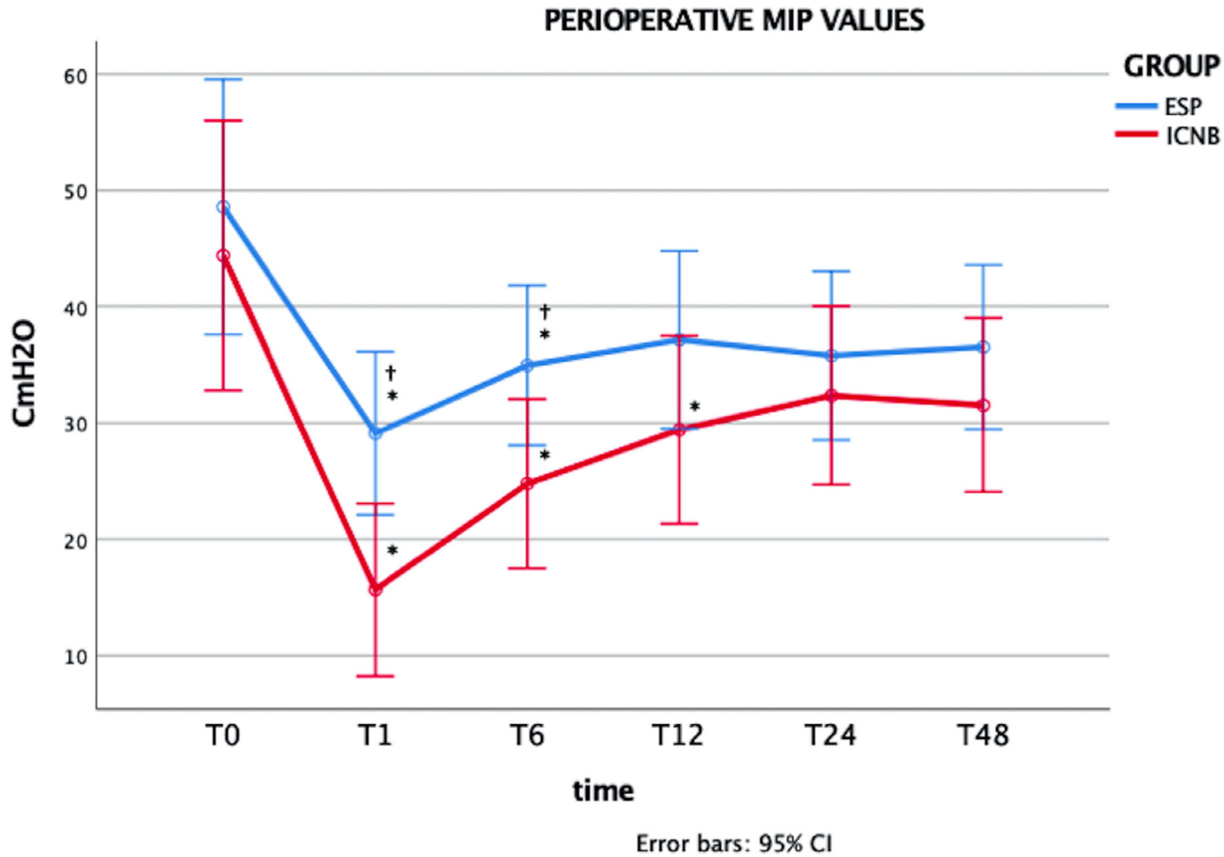


Fig 5. Maximal inspiratory pressure (MIP) medium values. ESP, erector spinae plane; ICNB, intrapleural intercostal nerve block. *$p < 0.05$, compared to previous test; †, $p < 0.05$, ESPB compared to ICNB.

and single-injection ESPB.[20] However, the lower concentration of local anesthetic (0.375% ropivacaine) in the latter study might have been responsible for insufficient analgesia.

Decreases in postoperative pulmonary function after lung resection appear to be multifactorial events including loss of parenchyma, post-thoracotomy pain, and the presence of chest tube drainages. Effective postoperative regional analgesia can minimize the impairment of pulmonary function and play a crucial role in preventing postoperative pulmonary complications.[35] Measurements of respiratory muscle strength, such as MIP and MEP, are simple to perform. They provide a helpful indicator of muscle weakness and are useful follow-up tools during the postoperative period. MIP and MEP can be used to measure the combined effect of all muscles used during maximal effort.[36] Although respiratory muscle strength was better preserved in the ESPB patients, the MIP and MEP values decreased in the first hour postoperatively in both groups and then gradually increased. This phenomenon probably could be explained by other general anesthesia-related factors involved in the development of respiratory muscle weakness, such as the use of muscle relaxants, intraoperative opioids, and mechanical ventilation itself.[37] In particular, one-lung ventilation has been shown to be an independent cause of diaphragmatic dysfunction after anesthesia.[38] More effective postoperative regional analgesia after surgery, such as the ESPB, might have reduced the impairment of respiratory function and preserved the muscle strength.

Limitations of the study are as follows: (1) only a patient-dependent evaluating pain score was used in the postoperative period, whereas cutaneous sensory tests to document ESPB or ICNB were not used; (2) the study was single-blinded, because the patients received ESPB before induction of general anesthesia; and (3) although the occurrence of postoperative complications was investigated, the clinical effects of ESPB were not among the endpoints of the study. However, no difference in the occurrence of postoperative complications was found between the 2 groups. Further prospective larger studies are needed to evaluate this issue.

In conclusion, the present study showed that ESPB, as part of multimodal pain management, provided statistically significant superior analgesia and resulted in lower requests for additional analgesics and perioperative opioid use, compared with ICNB for post-minithoracotomy pain management. In the authors' setting, ESPB block ensured effective and superior pain control with the advantages of a single administration site, whereas the ICNB requires multiple injections. Moreover, ESPB patients showed lower impairment of postoperative respiratory muscle strength. Therefore, ESPB could be considered a viable choice for perioperative pain management for minithoracotomy surgical access.

## Conflict of Interest

The authors declare that there are no conflicts of interest.

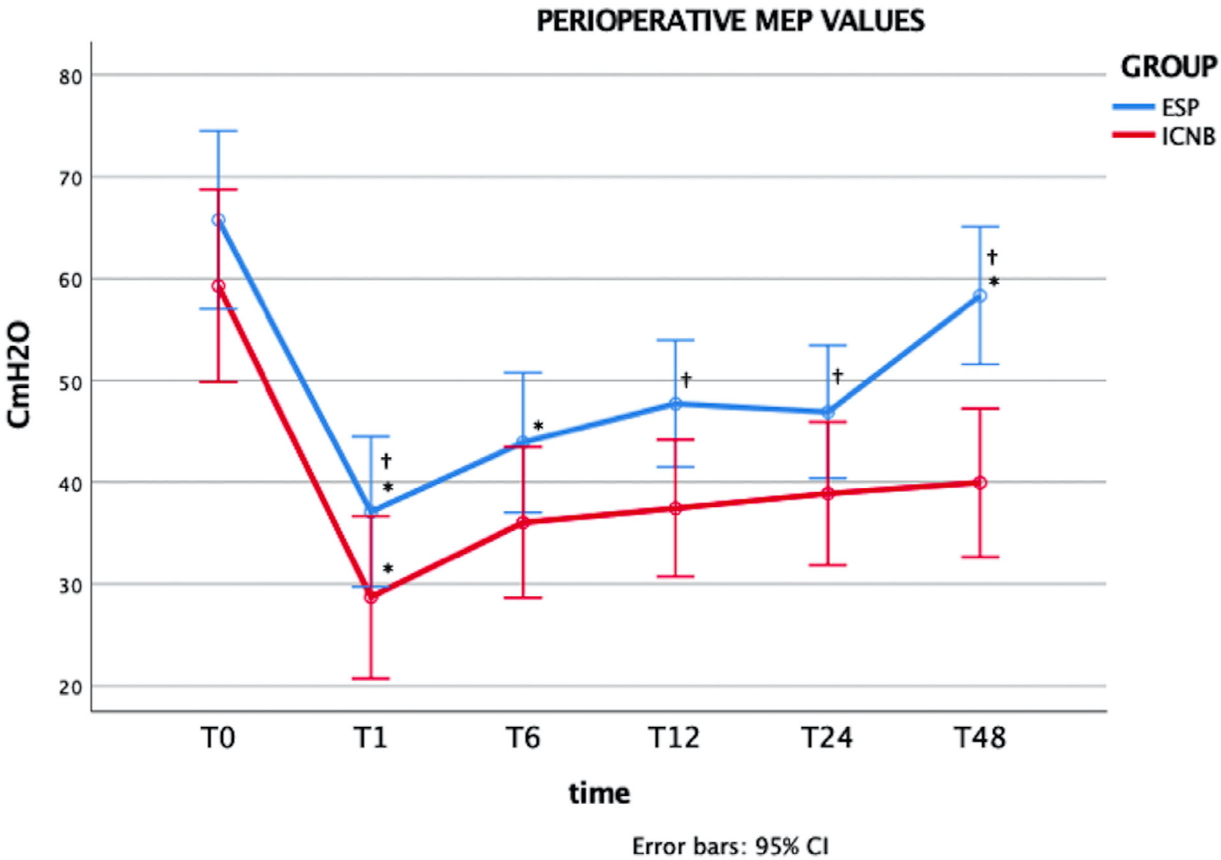


Fig 6. Maximal expiratory pressure (MEP) medium values. ESP, erector spinae plane; ICNB, intrapleural intercostal nerve block. *p < 0.05, compared to previous test; †, p < 0.05, ESPB compared to ICNB.

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