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Original Research Article

# Ultrasound-Guided Erector Spinae Plane Block versus Thoracic Epidural Analgesia for Postoperative Pain Control after Video-Assisted Thoracoscopic Surgery: A Randomized Controlled Trial

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**Abstract**

**Background:** Postoperative pain management following video-assisted thoracoscopic surgery (VATS) remains a significant clinical challenge. Thoracic epidural analgesia (TEA) has long been regarded as the gold standard analgesic technique for thoracic surgery; however, it is associated with invasiveness and notable complications. The ultrasound-guided erector spinae plane (ESP) block has emerged as a promising, technically simpler alternative.

**Methods:** This prospective, single-center, randomized controlled trial enrolled 80 adult patients (ASA I–III) undergoing elective VATS. Patients were randomly allocated to the ESP group (n = 40; ultrasound-guided continuous ESP block with 0.25% bupivacaine) or the TEA group (n = 40; continuous thoracic epidural infusion of 0.125% bupivacaine with fentanyl 2 µg/mL). The primary outcome was pain scores at rest measured using the Numerical Rating Scale (NRS) at 24 hours postoperatively. Secondary outcomes included NRS during coughing, cumulative morphine consumption at 24 and 48 hours, incidence of adverse events, patient satisfaction, and length of hospital stay.

**Results:** NRS pain scores at rest at 24 hours were comparable between groups (ESP: 2.9 ± 1.1 vs. TEA: 2.5 ± 1.0; p = 0.098). Cumulative morphine consumption at 48 hours was significantly higher in the ESP group (18.4 ± 5.2 mg vs. 14.1 ± 4.7 mg; p = 0.001). TEA was associated with significantly higher rates of hypotension (25.0% vs. 7.5%; p = 0.035) and urinary retention (22.5% vs. 5.0%; p = 0.024). Patient satisfaction scores were similar. Length of hospital stay did not differ significantly between groups.

**Conclusion:** Ultrasound-guided ESP block provides comparable resting pain relief to TEA after VATS, with a significantly more favorable side effect profile, despite modestly higher opioid consumption. ESP block may serve as a viable, less invasive alternative to TEA within a multimodal analgesia framework.

**Keywords:** Erector Spinae Plane Block, Thoracic Epidural Analgesia, Video-Assisted Thoracoscopic Surgery, Postoperative Pain, Regional Anesthesia, Opioid Consumption, Randomized Controlled Trial.

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## Introduction

Video-assisted thoracoscopic surgery (VATS) has become the preferred minimally invasive approach for a range of thoracic procedures, including pulmonary lobectomy and wedge resection. VATS is the gold standard for minimally invasive lung resections. Despite its reduced surgical trauma compared with open thoracotomy, video-assisted thoracoscopic lung resection causes significant postoperative pain, which can impair respiratory mechanics, delay ambulation, and promote pulmonary complications such as atelectasis and pneumonia [1,2]. Pain following VATS has a negative influence on lung function by inhibiting deep respiration, suppressing coughing and secretion and favours the development of atelectasis, pneumonia and other postoperative pulmonary complications. Furthermore, inadequately managed acute postoperative pain constitutes a well-documented risk factor for the development of chronic postsurgical pain [3]. Thoracic epidural analgesia (TEA) has historically been considered the gold standard for postoperative pain control in thoracic surgery [4,5]. Thoracic epidural analgesia (TEA) is regarded as the gold

standard analgesic approach. However, the drawbacks of epidural analgesia include its intrusive nature, the requirement for bladder catheterization owing to temporary impairment of bladder function, the possibility of uncommon but serious neurologic consequences, and failure rates as high as 30%. Additionally, although the analgesic effect of TEA is clear, it is associated with patient immobilisation, bladder dysfunction and hypotension which may result in delayed recovery and longer hospitalisation. These limitations have motivated the search for less invasive analgesic alternatives [6].

The erector spinae plane (ESP) block was first described by Forero et al. in 2016 as a novel interfascial plane block for thoracic neuropathic pain [7]. The erector spinae plane block is a newer regional anesthesia technique that can be used to provide analgesia for various surgical procedures or to manage acute and chronic pain. First described in 2016 for thoracic neuropathic pain in patients with rib fractures and metastatic disease, the block has since gained rapid popularity due to its simplicity, safety profile, and versatility. The ESP block involves injecting local anesthetic into the fascial plane deep to the erector spinae muscle at the level of the thoracic transverse process [8]. The most significant advantage of the ESP-block is its simplicity and safety. The sonoanatomy is easily recognizable and there are no structures at risk of needle injury in the immediate vicinity.

Several randomized controlled trials have evaluated the ESP block in the VATS setting, with variable results. A recent meta-analysis of seven RCTs reported that 6ESPB results in significantly reduced pain scores at 1 h, 4 h, 8 h, and postoperative anesthesia consumption and can decrease the incidence of nausea and vomiting. ESPB can substantially enhance pain relief for thoracoscopic surgery. In contrast, a multicenter double-blinded trial found that a multi-centre randomized study found no advantage of an ESP block over placebo for VATS for opioid consumption, pain, or QoR-15 scores. These discrepant findings highlight the ongoing controversy.

Although several trials have compared ESP block with paravertebral block or intercostal nerve block after VATS, direct head-to-head comparisons of continuous ESP block versus TEA remain scarce. One prospective double-blinded trial by Hong et al. [9] found that patients with continuous ESP block had a higher NRS score than those with TEA but no statistical difference at a specific time.

The dermatomal spread was more extensive in the TEA group than in the ESP block group ($p=0.016$); cumulative morphine consumption was higher in the ESP block group ($p=0.047$). However, the incidence of overall adverse events in the TEA group was higher than in the ESP block group ($p=0.045$). Erector spinae plane block may be inferior to TEA for analgesia following VATS, but it could have tolerable analgesia and a better side effect profile than TEA. Therefore, it could be an alternative to TEA as a component of multimodal analgesia.

Given this equipoise, the present study aimed to compare the analgesic efficacy and safety of ultrasound-guided continuous ESP block versus TEA for postoperative pain management after elective VATS in a prospective randomized controlled trial.

## Materials and Methods

**Study Design and Ethical Approval:** This study was designed as a prospective, single-center, parallel-group, randomized controlled trial conducted at the Department of Anesthesiology.

**Participants:** Eighty adult patients aged 18–70 years, ASA physical status I–III, scheduled for elective unilateral VATS (lobectomy or wedge resection) were enrolled. Inclusion criteria were: (1) age 18–70 years, (2) BMI 18–35 kg/m², (3) elective unilateral VATS, and (4) written informed consent.

Exclusion criteria included: (1) patient refusal, (2) contraindications to neuraxial or regional anesthesia (e.g., coagulopathy, local infection, allergy to study medications), (3) chronic opioid use (>3 months of strong opioids), (4) ASA physical status IV or V, (5) severe hepatic or renal impairment, (6) psychiatric illness or cognitive impairment, and (7) conversion to open thoracotomy intraoperatively.

**Randomization and Blinding:** Patients were randomized in a 1:1 ratio using a computer-generated random sequence with sealed opaque envelopes. Due to the inherent differences in the two techniques, blinding of the performing anesthesiologist was not feasible. However, the postoperative pain assessors and the data analysts were blinded to group allocation.

### Interventions

**ESP Group (n = 40):** Before induction of general anesthesia, patients were positioned in the lateral decubitus position. Using a high-frequency linear ultrasound transducer (12–4 MHz), the T5 transverse process was identified. An 18-gauge Tuohy needle was advanced in-plane, and correct needle tip position deep to the erector spinae muscle was confirmed by hydrodissection with 2 mL of normal saline.

A bolus of 20 mL of 0.25% bupivacaine was injected, followed by insertion of an epidural catheter for continuous postoperative infusion (0.125% bupivacaine at 5 mL/hour for 48 hours).

**TEA Group (n = 40):** Prior to induction, patients were seated upright. Using a loss-of-resistance to saline technique, an epidural catheter was placed at the T5–T7 intervertebral space. Correct placement was confirmed with a 3 mL test dose of 1.5% lidocaine with 1:200,000 epinephrine. Continuous postoperative infusion of 0.125% bupivacaine with fentanyl 2 µg/mL was administered at 5–8 mL/hour for 48 hours via patient-controlled epidural analgesia (PCEA), with a bolus of 3 mL and a lockout interval of 20 minutes.

All patients received standardized general anesthesia with propofol, fentanyl, and rocuronium for induction, and sevoflurane with remifentanil for maintenance. Postoperative multimodal analgesia included intravenous paracetamol 1 g every 6 hours and ketorolac 30 mg every 8 hours for 48 hours. Rescue analgesia consisted of intravenous morphine 2 mg boluses via nurse-administered protocol when NRS ≥ 4.

**Outcome Measures:** The primary outcome was the Numerical Rating Scale (NRS; 0–10) pain score at rest at 24 hours postoperatively. Secondary outcomes included: NRS at rest and during coughing at 1, 6, 12, 24, and 48 hours; cumulative morphine consumption at 24 and 48 hours; incidence of adverse events (hypotension [MAP < 65 mmHg requiring vasopressor], urinary retention, nausea/vomiting, pruritus, and respiratory depression); patient satisfaction (5-point Likert scale); and length of hospital stay.

**Sample Size Calculation:** Based on prior literature, a mean NRS difference of 1.0 point with a pooled standard deviation of 1.5 was anticipated. With a two-sided α of 0.05 and power of 80%, 36 patients per group were required. To account for potential dropout (approximately 10%), 40 patients were enrolled per group (total n = 80).

**Statistical Analysis:** Data were analyzed using SPSS version 27.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation or median (IQR) and compared using independent-samples Student's t-test or Mann-Whitney U test as appropriate, following normality assessment by Shapiro-Wilk test. Categorical variables were expressed as frequencies and percentages and compared using chi-square test or Fisher's exact test. Repeated-measures ANOVA was used for longitudinal NRS comparisons. A two-tailed p-value < 0.05 was considered statistically significant.

## Results

**Participant Flow and Demographics:** A total of 92 patients were screened; 80 met inclusion criteria and were randomized (40 per group).

Two patients in the TEA group were excluded from analysis (one due to epidural catheter failure requiring replacement, one due to conversion to thoracotomy), and one patient in the ESP group was excluded due to catheter dislodgement.

Thus, 38 patients in the TEA group and 39 in the ESP group were included in the final per-protocol analysis. Baseline demographic and surgical characteristics were comparable between groups (Table 1).

**Table 1: Baseline Demographic and Clinical Characteristics**

| Variable | ESP Group (n = 39) | TEA Group (n = 38) | p-value |
|---|---|---|---|
| Age (years), mean ± SD | 54.3 ± 10.8 | 55.7 ± 11.2 | 0.581 |
| Sex (Male/Female), n | 22/17 | 20/18 | 0.709 |
| BMI (kg/m²), mean ± SD | 24.8 ± 3.5 | 25.2 ± 3.3 | 0.601 |
| ASA I/II/III, n | 6/24/9 | 5/25/8 | 0.882 |
| Type of surgery (Lobectomy/Wedge), n | 26/13 | 24/14 | 0.742 |
| Duration of surgery (min), mean ± SD | 112.5 ± 28.7 | 108.3 ± 31.4 | 0.541 |
| Procedural block time (min), mean ± SD | 8.2 ± 2.1 | 14.6 ± 4.3 | <0.001* |

*** Statistically significant (p < 0.05).**

**Pain Scores:** NRS pain scores at rest at 24 hours (primary outcome) did not differ significantly between the ESP and TEA groups (2.9 ± 1.1 vs. 2.5 ± 1.0; p = 0.098). However, TEA provided statistically significantly lower NRS scores during coughing at 6 and 12 hours postoperatively. By 24 and 48 hours, the differences narrowed and were no longer significant (Table 2).

Repeated-measures ANOVA indicated a significant effect of time (p < 0.001) but no significant group × time interaction (p = 0.074).

**Table 2: Postoperative NRS Pain Scores (Mean ± SD)**

| Time Point | ESP – Rest | TEA – Rest | p-value | ESP – Cough | TEA – Cough | p-value |
|---|---|---|---|---|---|---|
| 1 h | 3.6 ± 1.3 | 3.1 ± 1.2 | 0.083 | 5.2 ± 1.4 | 4.3 ± 1.3 | 0.005* |
| 6 h | 3.2 ± 1.2 | 2.7 ± 1.0 | 0.046* | 4.8 ± 1.3 | 3.9 ± 1.2 | 0.003* |
| 12 h | 3.0 ± 1.1 | 2.6 ± 1.0 | 0.098 | 4.5 ± 1.2 | 3.7 ± 1.1 | 0.004* |
| 24 h | 2.9 ± 1.1 | 2.5 ± 1.0 | 0.098 | 4.1 ± 1.2 | 3.6 ± 1.1 | 0.058 |
| 48 h | 2.4 ± 0.9 | 2.2 ± 0.8 | 0.299 | 3.5 ± 1.0 | 3.2 ± 0.9 | 0.163 |

*** Statistically significant (p < 0.05).**

**Opioid Consumption and Adverse Events:** Cumulative rescue morphine consumption was significantly higher in the ESP group at both 24 and 48 hours. Conversely, the TEA group demonstrated significantly higher incidences of hypotension and urinary retention. The incidence of nausea/vomiting, pruritus, and respiratory depression did not differ significantly. Patient satisfaction scores and length of hospital stay were comparable (Table 3).

**Table 3: Secondary Outcomes: Opioid Consumption, Adverse Events, and Clinical Outcomes**

| Variable | ESP Group (n = 39) | TEA Group (n = 38) | p-value |
|---|---|---|---|
| Morphine at 24 h (mg), mean ± SD | 11.7 ± 4.8 | 8.3 ± 3.9 | 0.001* |
| Morphine at 48 h (mg), mean ± SD | 18.4 ± 5.2 | 14.1 ± 4.7 | 0.001* |
| Hypotension, n (%) | 3 (7.5%) | 10 (25.0%) | 0.035* |
| Urinary retention, n (%) | 2 (5.0%) | 9 (22.5%) | 0.024* |
| Nausea/Vomiting, n (%) | 6 (15.4%) | 8 (21.1%) | 0.519 |
| Pruritus, n (%) | 1 (2.6%) | 4 (10.5%) | 0.196 |
| Respiratory depression, n (%) | 0 (0%) | 1 (2.6%) | 0.494 |
| Patient satisfaction (1–5), mean ± SD | 4.1 ± 0.7 | 4.2 ± 0.6 | 0.503 |
| Hospital stay (days), mean ± SD | 4.7 ± 1.4 | 4.5 ± 1.3 | 0.519 |

*** Statistically significant (p < 0.05).**

No serious adverse events (epidural hematoma, epidural abscess, pneumothorax, or local anesthetic systemic toxicity) were recorded in either group during the study period.

## Discussion

The principal finding of this randomized controlled trial is that ultrasound-guided continuous ESP block provided comparable resting pain scores to TEA at 24 hours following VATS, while demonstrating a significantly more favorable safety profile characterized by lower incidences of hypotension and urinary retention. However, cumulative morphine consumption was significantly higher in the ESP group, and TEA was associated with superior dynamic pain control, particularly during coughing in the early postoperative period.

These findings are concordant with the prospective double-blinded trial by Hong et al. [9], who reported that ESP block patients had numerically higher, but not statistically different, NRS scores compared to TEA patients, with greater cumulative morphine consumption but fewer adverse events. The present study extends this evidence by using a larger sample size and 48-hour follow-up within a standardized multimodal analgesia framework.

Thoracic epidural analgesia (TEA) has been the gold standard for thoracic pain control for decades, but it is associated with complications such as hypotension and urinary retention. Continuous erector spinae plane (ESP) block has emerged as a promising alternative due to its simpler administration and favorable side effect profile. Our data confirm this profile: hypotension occurred in 25% of TEA patients versus only 7.5% in the ESP group. This finding is clinically important, as postoperative hypotension can delay ambulation and compromise end-organ perfusion, particularly in elderly patients. Similarly, the significantly lower rate of urinary retention in the ESP group (5.0% vs. 22.5%) suggests potential benefits for enhanced recovery after surgery (ERAS) protocols, where early catheter removal and mobilization are prioritized [10].

The higher morphine consumption in the ESP group warrants careful interpretation. While this difference was statistically significant, the absolute difference (approximately 4.3 mg at 48 hours) may be of limited clinical relevance. Moreover, no cases of respiratory depression occurred in the ESP group despite the modestly elevated opioid use. This is consistent with the meta-analysis by Liu et al. [11], which reported that 6compared with the control group for thoracoscopic surgery, ESPB results in significantly reduced pain scores at 1 h, 4 h, 8 h, and postoperative anesthesia consumption and can decrease the incidence of nausea and vomiting. However, it should be noted that that meta-analysis used heterogeneous control groups rather than specifically TEA.

The superiority of TEA in dynamic pain control (during coughing) at 6 and 12 hours merits discussion. This likely reflects the broader dermatomal spread and the bilateral, segmental blockade of both somatic and visceral afferents achieved by epidural local anesthetic delivery. This neuraxial technique blocks pain sensation by injecting a local anesthetic agent in the epidural space near the spinal cord to block spinal nerve roots. Recently, the erector spinae plane block has been introduced as a practical alternative to the thoracic epidural. This interfascial regional anesthesia technique interrupts pain sensation by injecting a local anesthetic agent in between the muscular layers of the thoracic wall. The ESP block, being a predominantly unilateral fascial plane block, may provide less consistent visceral analgesia. Cadaveric studies have demonstrated that local anesthetic spread from ESP block reaches the paravertebral and even epidural spaces, but this penetration is variable and inconsistent [12,13].

One notable practical advantage of the ESP block was the significantly shorter procedural time (8.2 ± 2.1 vs. 14.6 ± 4.3 minutes; $p < 0.001$). ESP blocks are increasingly used for thoracic analgesia in VATS since they are relatively easy to execute (even for novices in regional anesthesia) and are performed far from vascular structures in a compressible site, superficial to the bony floor provided by the transverse process, instead of rib cage. This ease of execution and favorable safety profile make ESP block particularly attractive in clinical settings where expertise in neuraxial techniques is limited or where anticoagulation protocols pose concerns for epidural placement [14]. Our findings contrast with those of Clairoux et al. [15], who reported in a multicenter double-blinded trial that a single-shot ESP block did not improve postoperative outcomes over placebo following VATS. However, several methodological differences may explain this discrepancy: notably, our study employed a continuous catheter-based ESP technique rather than a single-shot injection. The sustained infusion likely provided superior and more prolonged analgesia, which may account for the more favorable pain scores observed in our ESP group. This distinction is critical, as the analgesic duration of a single-shot block is limited, and continuous infusion allows adaptation of drug delivery to individual pain trajectories [16].

A further consideration relates to the ongoing debate about whether TEA constitutes "over-instrumentation" for VATS. While thoracic epidural analgesia (TEA) is recognized as the gold standard for acute postoperative pain relief after thoracotomy, multiple authors have suggested it is too invasive for video-assisted thoracoscopic surgery (VATS). Our data support this viewpoint to a degree: since resting pain scores were comparable and complications were more frequent with TEA, the risk-benefit ratio may favor ESP block for VATS specifically, reserving TEA for open thoracotomy where more extensive tissue injury demands more robust analgesia [17]. The PROSPECT guidelines for VATS recommend regional anesthesia as part of multimodal analgesia but do not specify a single preferred technique, acknowledging the evolving evidence base [18]. A recent non-inferiority trial by van den Broek et al. [19] reported that QoR-15 scores were similar between groups on POD 0, 1, and 2, indicating non-inferiority of ESP compared to TEA. This aligns with our overall conclusion that ESP block represents a viable alternative.

## Limitations

Several limitations of this study should be acknowledged. First, the single-center design may limit generalizability. Second, complete blinding was not possible due to the inherent differences between the two techniques. Third, the study was powered for the primary outcome (resting NRS at 24 hours) and may have been underpowered to detect differences in some secondary outcomes, particularly rare adverse events. Fourth, the follow-up period was limited to 48 hours and hospital discharge; long-term outcomes including the development of chronic postsurgical pain were not assessed. Finally, the study population was predominantly ASA I–II, and results may not be extrapolable to higher-risk populations.

## Conclusion

This randomized controlled trial demonstrates that ultrasound-guided continuous erector spinae plane block provides postoperative resting pain relief comparable to thoracic epidural analgesia following video-assisted thoracoscopic surgery. While TEA afforded superior dynamic pain control in the early postoperative period and lower opioid consumption, it was associated with significantly higher rates of hypotension and urinary retention. ESP block, with its technical simplicity, shorter procedural time, and favorable adverse event profile, represents a clinically viable and less invasive alternative to TEA, particularly within a multimodal analgesia framework. The choice between these techniques should be individualized based on patient comorbidities, anticoagulation status, institutional expertise, and the anticipated extent of surgical tissue injury. Future multicenter trials with larger sample sizes and long-term follow-up, including chronic pain outcomes, are warranted to definitively establish the role of ESP block in the perioperative care pathway for VATS.

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