



**THE TRADE-OFF BETWEEN ANALGESIC POTENCY AND
PROCEDURAL SAFETY: ERECTOR SPINAE PLANE BLOCK VERSUS
THE GOLD-STANDARD THORACIC PARAVERTEBRAL BLOCK IN
UNIORTAL AND MULTIORTAL VIDEO-ASSISTED THORACOSCOPIC
SURGERY — A SYSTEMATIC REVIEW AND META-ANALYSIS OF
RANDOMIZED CONTROLLED TRIALS AND PRIMARY STUDIES**

Stien Julia Risky Hetharie^{1*}, Jofetrin Lewerissa²

¹ Air Salobar Public Health Center, Ambon City, Maluku, Indonesia

² Dr. H. Ishak Umarella Regional Public Hospital, Central Maluku Regency, Maluku, Indonesia

***Corresponding author:** Stien Julia Risky Hetharie, Air Salobar Public Health Center, Ambon City, Maluku, Indonesia. Email: kikyhetharie@gmail.com; Phone: +62 852 8222 2942

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ABSTRACT

Introduction: Uniportal and multiportal video-assisted thoracoscopic surgery (VATS) reduce surgical trauma, yet moderate-to-severe acute pain remains common and predisposes to pulmonary complications and chronic postsurgical pain (CPSP). The thoracic paravertebral block (TPVB) is regarded as the regional "gold standard", whereas the erector spinae plane block (ESPB) is technically simpler and theoretically safer. Whether ESPB trades analgesic potency for procedural safety has not been quantified jointly. We aimed to compare the analgesic efficacy, opioid-sparing effect, recovery quality and procedural safety of ESPB versus TPVB, hypothesising that TPVB provides superior early analgesia, that both blocks converge beyond the early period, and that ESPB carries fewer block-related complications.

Methods: The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines were searched from January 2011 to September 2026, supplemented by citation searching. Randomised controlled trials (RCTs), comparative cohorts and comparative case series directly comparing ESPB with TPVB in minimally invasive thoracic surgery were eligible. Risk of bias was assessed with RoB 2 and the Newcastle–Ottawa Scale. Random-effects (DerSimonian–Laird) meta-analyses generated mean differences (MD), standardised mean differences (SMD) and risk ratios (RR); rare block-related complications were pooled with the Peto odds ratio (OR). Certainty was graded with GRADE.

Results: Twenty-seven studies (24 RCTs, 3 cohorts; 2,015 participants; 26 thoracic studies, $n = 1,960$) were included and 20 contributed to 21 meta-analyses. TPVB produced lower rest pain at 0–2 h (MD 0.41, 95% CI 0.02–0.81; $I^2 = 84\%$), an advantage below the 1-point minimal clinically important difference that disappeared from 6 h onward (24 h: MD 0.13, –0.20 to 0.46; 48 h: MD –0.08, –0.24 to 0.09). Dynamic pain did not differ at any time point. Twenty-four-hour opioid consumption showed a borderline opioid-sparing effect of TPVB (SMD 0.35, –0.00 to 0.71; $p = 0.051$), significant in adults only (SMD 0.41, 0.04–0.79). Rescue analgesia (RR 1.21, 0.83–1.77), PONV (RR 1.00, 0.75–1.34), hypotension (RR 0.60, 0.18–1.97), QoR-15 (MD 1.19, –4.80 to 7.17), length of stay (MD –0.13 days, –0.38 to 0.12) and CPSP (RR 0.96, 0.68–1.34) were comparable. Block-related complications (pneumothorax, pleural puncture, haematoma, unintended epidural spread) were markedly less frequent with ESPB (1/276 vs 15/270; Peto OR 0.15, 0.05–0.40; $p < 0.001$).

Discussion: The ESPB–TPVB relationship is a time-dependent trade-off: TPVB buys a small, short-lived gain in early somatic analgesia and possibly opioid sparing at the price of a roughly seven-fold higher odds of block-related complications, whereas analgesia, recovery quality and long-term pain converge thereafter. Certainty was low to very low for most efficacy outcomes and moderate for safety, length of stay and CPSP.

Conclusion: ESPB is a safer, analgesically comparable alternative to TPVB for (uniportal) VATS beyond the first postoperative hours. TPVB may be reserved for patients in whom maximal early analgesia is prioritised and procedural risk is acceptable.

Keywords: erector spinae plane block; thoracic paravertebral block; uniportal video-assisted thoracoscopic surgery; postoperative analgesia; regional anaesthesia; patient safety; meta-analysis

INTRODUCTION

Video-assisted thoracoscopic surgery (VATS) has become the predominant approach for anatomical lung resection, and the progressive shift from multiportal to uniportal VATS (uVATS) confines access to a single intercostal space. Comparative data indicate that strictly defined uVATS reduces 24-h pain by approximately 2.5 points on a 10-point scale and lowers opioid requirements compared with multiportal VATS, with fewer patients requiring analgesics up to postoperative day 90.^{1,2} Nevertheless, intercostal nerve compression, chest-drain irritation and parietal pleural injury still generate moderate-to-severe acute pain in a substantial proportion of patients, and acute postoperative pain is the strongest independent predictor of early persistent pain, which affects approximately one in six patients after VATS.³⁻⁵

Contemporary procedure-specific (PROSPECT) recommendations endorse either a paravertebral block or an erector spinae plane block as first-choice regional techniques for VATS within a multimodal regimen, explicitly no longer recommending thoracic epidural analgesia.⁶ The thoracic paravertebral block (TPVB) deposits local anaesthetic directly into the wedge-shaped paravertebral space bounded by the superior costotransverse ligament and the parietal pleura, producing dense unilateral somatic and sympathetic blockade; for this reason it has long been regarded as the regional "gold standard" for thoracic surgery.^{4,7,8} Its proximity to the pleura, segmental vessels and neuraxis, however, exposes patients to pneumothorax, pleural puncture, non-compressible haematoma, unintended epidural spread and sympathectomy-related hypotension.^{7,9,10}

The erector spinae plane block (ESPB), first described by Forero and colleagues in 2016, targets the fascial plane deep to the erector spinae muscle at the tip of the transverse process, which acts as an acoustic and mechanical backstop far from the pleura.¹¹ Local anaesthetic subsequently spreads craniocaudally and, to a variable extent, anteriorly through the costotransverse foramina and intertransverse tissues into the paravertebral and epidural spaces, acting on dorsal and ventral rami.^{7,11} Because this ventral spread is indirect and inconsistent, sensory mapping studies have documented fewer anaesthetised (particularly parasternal) dermatomes after ESPB than after TPVB, and magnetic resonance imaging has shown injectate confined to the erector spinae plane 30 min after injection in some patients.^{10,12,13}

Randomised and observational evidence is conflicting. Several trials and a large single-port cohort found superior analgesia or opioid sparing with TPVB,¹⁴⁻¹⁷ whereas others demonstrated non-inferiority, equivalence or even superiority of ESPB, together with better

recovery quality in catheter-based comparisons.^{9,18–21} Previous meta-analyses pooled thoracotomy with VATS, focused almost exclusively on pain and opioid outcomes, and predate the 2025–2026 trials; network meta-analyses ranked TPVB first for opioid sparing while describing ESPB as a viable alternative.^{22–28}

The research gap is therefore threefold. First, no synthesis has quantified analgesic potency and procedural safety simultaneously as two sides of a single clinical trade-off. Second, block-related complications—individually rare—have not been pooled with methods appropriate for sparse events. Third, uniportal, single-incision and paediatric thoracoscopic data, as well as recent trials from 2025–2026, remain unintegrated.^{29–33} The novelty of the present review lies in a time-stratified efficacy analysis (0–2, 6–8, 12, 24 and 48 h), a Peto-based safety synthesis, inclusion of RCTs together with comparative primary studies, explicit uVATS context and a GRADE-anchored decision algorithm.

Accordingly, the objective of this systematic review and meta-analysis was to compare ESPB with TPVB for perioperative analgesia in uniportal and multiportal VATS with respect to pain intensity, opioid consumption, recovery quality, procedural efficiency and safety. We hypothesised that (H1) TPVB provides superior early (0–2 h) analgesia; (H2) analgesic efficacy converges from 6 h onward; and (H3) ESPB is associated with fewer block-related complications. The anticipated benefit is an evidence-based, patient-tailored framework for block selection in thoracic anaesthesia and enhanced recovery programmes.

METHODS

Protocol and reporting

This review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement, and the literature search was documented according to the PRISMA-S extension.^{34,35} The protocol, including eligibility criteria, outcomes and analysis plan, was finalised by both authors before data extraction; it was not prospectively registered, which is acknowledged as a limitation.

Eligibility criteria

Eligibility followed the PICOS framework summarised in Table. Studies were eligible if they directly compared ESPB with TPVB in patients undergoing elective minimally invasive thoracic surgery and reported at least one prespecified outcome. Multi-arm trials were included when they contained separate ESPB and TPVB arms; only these two arms were extracted, and combination arms (e.g., TPVB + ESPB), intercostal nerve block arms and no-block control arms were excluded from quantitative synthesis to avoid unit-of-analysis errors.^{13,14,36} When both

arms received an identical co-intervention (e.g., intercostal nerve block), the comparison was retained because the contrast remained ESPB versus TPVB.^{9,37}

Table 1. Eligibility criteria according to the PICOS framework

Domain	Inclusion criteria	Exclusion criteria
Population	Adults (≥ 18 y) and children (2–18 y), ASA I–III, scheduled for elective multiportal or uniportal/single-incision VATS, robot-assisted thoracoscopic surgery or thoracoscopy-guided Nuss repair; paediatric truncal surgery with a thoracic-level block accepted only for prespecified sensitivity analyses	Emergency surgery; open thoracotomy or sternotomy populations; spinal deformity precluding blocks; conversion-only cohorts
Intervention	Ultrasound-guided ESPB: single-shot, multi-level, continuous catheter or programmed intermittent bolus; any local anaesthetic, adjuvant or volume	ESPB combined with a second fascial plane block that is not mirrored in the comparator arm
Comparator	TPVB: ultrasound-guided or surgeon-placed under thoracoscopic vision; single- or multi-level; single-shot or catheter	TPVB + ESPB combination as the only comparator; epidural, intercostal or serratus blocks as comparator
Outcomes	Pain at rest and on coughing (0–2, 6–8, 12, 24, 48 h); 24-h and 48-h opioid consumption; rescue analgesia; moderate-to-severe pain; time to first rescue; block performance time; QoR-15; length of stay; PONV; hypotension; block-related complications; LAST; CPSP	No extractable comparative outcome
Study design	RCTs, prospective or retrospective comparative cohorts (including propensity-score analyses) and comparative case series; January 2011–September 2026; English full text	Case reports, non-comparative series, letters, protocols, preprints, cadaveric/animal studies, narrative reviews; systematic reviews and meta-analyses

		(retained for discussion only); overlapping datasets
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Search Strategy

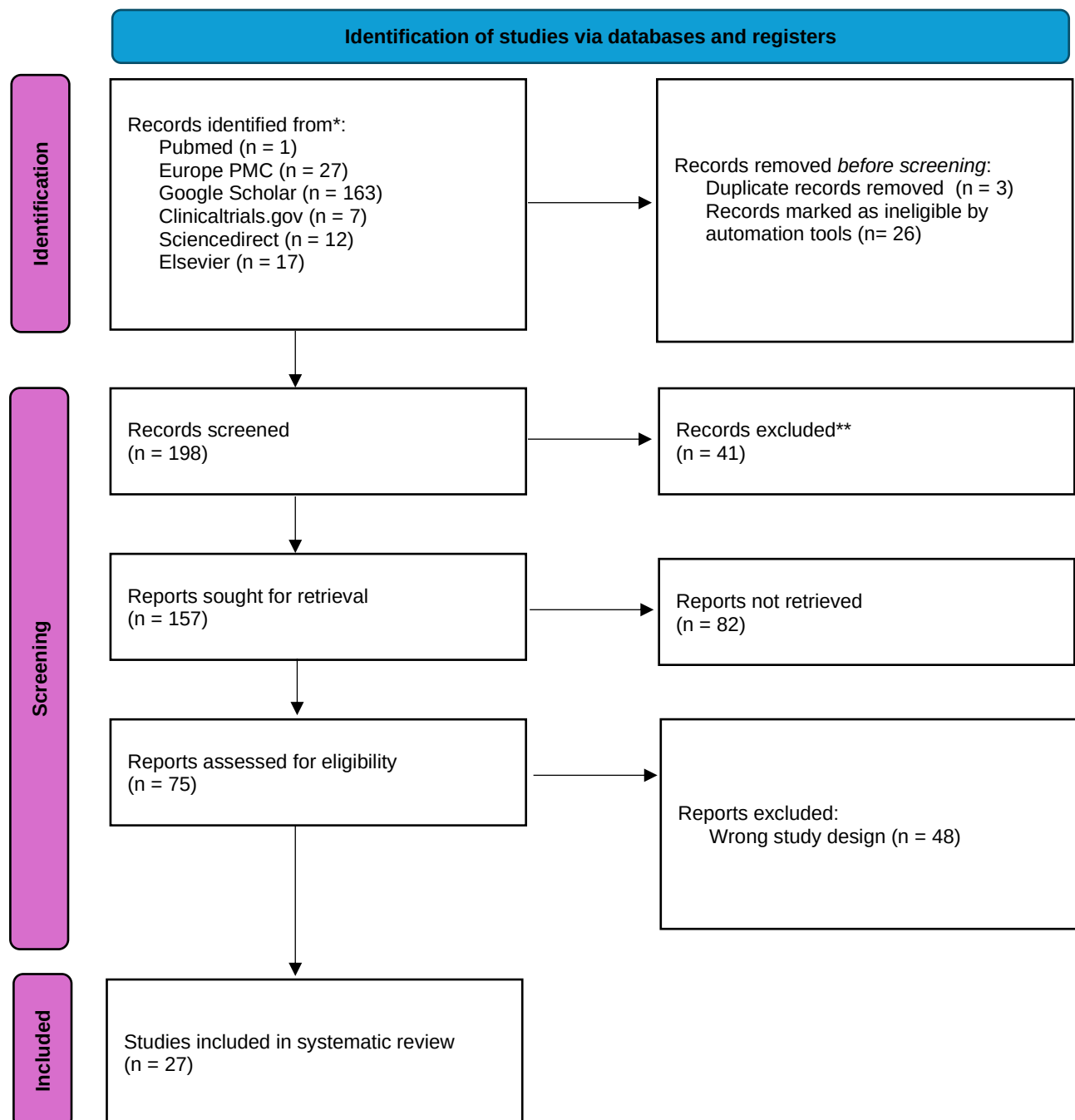
The keywords used for this research based PICO :

PICO Element	Keyword 1	Keyword 2	Keyword 3
P (Population)	Video-Assisted Thoracoscopic Surgery	Uniportal VATS	Multiportal VATS
I (Intervention)	Erector Spinae Plane Block	Regional Anaesthesia	Postoperative Analgesia
C (Comparison)	Thoracic Paravertebral Block	Gold-Standard Block	Paravertebral Analgesia
O (Outcome)	Analgesic Potency	Procedural Safety	Block-Related Complications

The Boolean MeSH keywords inputted on databases for this research are: ("Video-Assisted Thoracoscopic Surgery" OR "Uniportal VATS" OR "Multiportal VATS") AND ("Erector Spinae Plane Block" OR "Regional Anaesthesia" OR "Postoperative Analgesia") AND ("Thoracic Paravertebral Block" OR "Gold-Standard Block" OR "Paravertebral Analgesia") AND ("Analgesic Potency" OR "Procedural Safety" OR "Block-Related Complications")

Article Search Strategy

Database	Keywords	Hits
Pubmed	<i>("Video-Assisted Thoracoscopic Surgery" OR "Uniportal VATS" OR "Multiportal VATS") AND ("Erector Spinae Plane Block" OR "Regional Anaesthesia" OR "Postoperative Analgesia") AND ("Thoracic Paravertebral Block" OR "Gold-Standard Block" OR "Paravertebral Analgesia") AND ("Analgesic Potency" OR "Procedural Safety" OR "Block-Related Complications")</i>	1
Europe PMC	<i>("Video-Assisted Thoracoscopic Surgery" OR "Uniportal VATS" OR "Multiportal VATS") AND ("Erector Spinae Plane Block" OR "Regional Anaesthesia" OR "Postoperative Analgesia") AND ("Thoracic Paravertebral Block" OR "Gold-Standard Block" OR "Paravertebral Analgesia") AND ("Analgesic Potency" OR "Procedural Safety" OR "Block-Related Complications")</i>	27
Google Scholar	<i>("Video-Assisted Thoracoscopic Surgery" OR "Uniportal VATS" OR "Multiportal VATS") AND ("Erector Spinae Plane Block" OR "Regional Anaesthesia" OR "Postoperative Analgesia") AND ("Thoracic Paravertebral Block" OR "Gold-Standard Block" OR "Paravertebral Analgesia") AND ("Analgesic Potency" OR "Procedural Safety" OR "Block-Related Complications")</i>	163
Clinicaltrials.gov	<i>("Video-Assisted Thoracoscopic Surgery" OR "Uniportal VATS" OR "Multiportal VATS") AND ("Erector Spinae Plane Block") AND ("Thoracic Paravertebral Block") AND ("Analgesic Potency" OR "Procedural Safety" OR "Block-Related Complications")</i>	7
Science-direct	<i>("Video-Assisted Thoracoscopic Surgery" OR "Uniportal VATS" OR "Multiportal VATS") AND ("Erector Spinae Plane Block") AND ("Thoracic Paravertebral Block") AND ("Analgesic Potency" OR "Procedural Safety" OR "Block-Related Complications")</i>	12
Elsevier	<i>("Video-Assisted Thoracoscopic Surgery" OR "Uniportal VATS" OR "Multiportal VATS") AND ("Erector Spinae Plane Block") AND ("Thoracic Paravertebral Block") AND ("Analgesic Potency" OR "Procedural Safety" OR "Block-Related Complications")</i>	17



Article search flowchart

Study selection and data extraction

After deduplication, both authors independently screened titles and abstracts and then full texts against the eligibility criteria; disagreements were resolved by discussion. Using a piloted extraction form, both authors independently extracted bibliographic data, country, design, setting, sample size per arm, age, surgical approach (multiportal, uniportal/single-incision, robotic, Nuss), block technique (level, volume, concentration, single-shot or catheter,

operator), co-analgesia and rescue regimen, outcome definitions and time points, and adverse events. Data were cross-checked against tables, text and supplementary material; when the text and tables of a report conflicted, tabulated data were preferred and the discrepancy was recorded.³³

Data preparation and conversions

Medians with interquartile ranges or ranges were converted to means and standard deviations using the sample-size-dependent estimators of Wan and colleagues, and standard errors were derived from reported 95% confidence intervals when only between-group differences were available.^{39,40} Because 0–10 pain scores are discretised, a standard deviation floor of 0.5 points was applied when converted dispersion was implausibly narrow (e.g., an interquartile range of zero); a zero standard deviation for opioid consumption was imputed from the comparator arm. For propensity-score studies, covariate-adjusted between-group differences were preferred over crude estimates.²⁰ Because opioid consumption was reported for morphine, oxycodone, hydromorphone, sufentanil and oral morphine equivalents, it was pooled as the standardised mean difference (Hedges *g*).

Risk-of-bias assessment

Randomised trials were appraised with the revised Cochrane risk-of-bias tool (RoB 2) across five domains, yielding overall judgements of low risk, some concerns or high risk.⁴¹ Observational cohorts were appraised with the Newcastle–Ottawa Scale (NOS), the most frequently planned tool for non-randomised studies in registered reviews; scores ≥ 7 of 9 indicated good quality.⁴² Assessments were performed independently by both authors and reconciled by consensus.

Effect measures and synthesis

Effect sizes were expressed as ESPB minus TPVB, so that positive mean differences in pain or opioid consumption and risk ratios above 1 indicate a disadvantage of ESPB, whereas positive QoR-15 differences favour ESPB. Continuous outcomes measured on a common scale were pooled as mean differences (MD), opioid consumption as SMD, and dichotomous outcomes as risk ratios (RR) with a 0.5 continuity correction for single-zero cells; double-zero studies were displayed but not pooled. Because block-related complications were rare and frequently zero in one arm, they were pooled using the Peto one-step odds ratio. All other syntheses used DerSimonian–Laird random-effects models. Heterogeneity was quantified with Cochran's *Q*, *I*² and τ^2 , and 95% prediction intervals were calculated when five or more studies were available. A difference of 1 point on a 0–10 pain scale and 6 points on the QoR-15 were considered minimal clinically important differences (MCID).

Subgroup, sensitivity and reporting-bias analyses

Prespecified subgroup analyses compared RCTs with observational cohorts and thoracic with extended-population studies. Sensitivity analyses restricted pooling to RCTs, to adults, and to purely thoracoscopic populations, and leave-one-out analyses assessed the influence of individual studies. Small-study effects were explored with funnel plots and Egger's regression test for outcomes with nine or more studies, interpreting results cautiously below ten studies. Analyses and figures were produced with custom Python 3 code (NumPy, SciPy, Matplotlib) implementing standard inverse-variance, DerSimonian–Laird and Peto formulae.

Certainty of evidence

Certainty of evidence was rated with the GRADE approach. Evidence started at high certainty and was downgraded by one level for risk of bias when fewer than half of contributing studies were at low risk, for inconsistency when $I^2 \geq 50\%$, for imprecision when the total sample was below 400 participants, events were few, or the confidence interval crossed both no effect and the MCID, and for suspected publication bias when Egger's test was significant ($p < 0.10$) with ten or more studies.

RESULTS

Characteristics of included studies

The 27 studies were published between 2019 and 2026 and comprised 24 RCTs (23 thoracic and one extended-population trial) and three observational cohorts, two of which used propensity-score methods. Thirteen studies originated from China, six from Turkey, three from Egypt and one each from Japan, South Korea, Ireland, Brazil and France. Sample sizes ranged from 42 to 250, totalling 2,015 participants (1,960 in thoracic studies).^{9,12–15,18,19,21,36,37,52–54}

Three studies involved uniportal or single-incision VATS, three used continuous catheter techniques, two combined both blocks with an identical intercostal nerve block, and two enrolled children (Nuss repair and percutaneous nephrolithotomy). Multi-level ESPB (T4/T6 or T5/T8) and multi-injection TPVB (T5–T7) were used in a minority of trials, whereas most performed single-shot blocks at T4–T5 with 20–30 mL of ropivacaine, bupivacaine or levobupivacaine. Primary outcomes were pain intensity in 13 studies, opioid consumption in 7, QoR-15 in 4 and other endpoints in 3.^{10,16,17,20,29–33,55–59}

Table 2. Characteristics of the 27 included primary studies (systematic reviews and meta-analyses are not tabulated)

No	Study, country	Design	Population / surgery	n (ESPB/TPVB)	Age, y (ESPB/TPVB)	ESPB protocol	TPVB protocol	Outcomes; follow-up	Key findings
1	Taketa 2019, Japan ¹²	RCT, non-inferiority	VATS lung resection, adults	41/40	NR	Continuous ESPB; 20 mL 0.2% levobupivacaine bolus + 8 mL/h	Continuous TPVB; identical regimen	NRS rest/movement, dermatomes, plasma LA; 24 h	TPVB lower rest NRS at 1, 2, 24 h; ESPB non-inferior at 24 h; fewer parasternal dermatomes and lower plasma levobupivacaine with ESPB
2	Chen 2020, China ¹⁴	RCT, double-blind, 3-arm	Thoracoscopic partial lung resection, adults	24/24	18–75 (range)	Single-injection T5; 20 mL 0.375% ropivacaine	Multiple-injection T5–T7; 20 mL 0.375% ropivacaine	24-h morphine (PCA), VAS 0–48 h, rescue; 48 h	Morphine 22 vs 10.5 mg; more rescue with ESPB (46% vs 13%)
3	Zhao H 2020, China ¹⁸	RCT, blinded, non-inferiority	VATS, adults	33/33	NR	Bi-level T4 + T6; 30 mL 0.4%	Bi-level T4 + T6; 30 mL 0.4%	48-h oxycodone, pain, QoR-15;	ESPB non-inferior; equivalent pain

						ropivacaine	ropivacaine	48 h	and QoR-15
4	Çiftçi 2020, Turkey ⁵²	RCT, 3-arm	VATS, adults	30/30	NR	Single-shot, preoperative	Single-shot, preoperative	Fentanyl, VAS, block time; 24 h	Both superior to control; ESPB faster with higher single-puncture success
5	Turhan 2021, Turkey ¹⁵	RCT, single-blind, 3-arm	VATS, adults	35/35	NR	US-guided single-shot	US-guided single-shot	Dynamic VAS 1 h, morphine, rescue; 24 h	TPVB lower dynamic VAS at 24 h and lower 24-h morphine
6	Fu 2022, China ³⁶	RCT, double-blind, 3-arm	VATS, adults	20/22	57.3/58.6	20 mL 0.5% ropivacaine	20 mL 0.5% ropivacaine	Hydromorphone 12–48 h, VAS 0–72 h, rescue; 72 h	No ESPB–PVB difference in hydromorphone; cough VAS higher with ESPB at 12 h
7	Kim 2022, South Korea ⁹	RCT, single-blind, non-inferiority	VATS (lobectomy, segmentectomy, wedge), adults	26/26	60.3/62.4	T5; 20 mL 0.375% ropivacaine + ICNB	T5; 20 mL 0.375% ropivacaine + ICNB	VAS PACU/24/48 h, MME, safety; 48 h	ESPB+ICNB non-inferior; two pleural punctures with PVB

8	Sun 2022, China ³⁷	RCT, 3-arm	VATS lobectomy, adults	59/56	55.5/59.0	ESPB + ICNB	TPVB + ICNB	Moderate–severe pain, sufentanil, PONV, LOS; 48 h	Equivalent analgesia; two puncture-site haematomas with TPVB
9	Zhang JW 2022, China ⁵³	RCT, 3-arm	VATS lobectomy, adults	22/22	54.4/54.3	Single preoperative ESPB	Single preoperative TPVB	VAS rest/cough 1–48 h, sufentanil; 48 h	TPVB lower rest VAS at 12 h; otherwise comparable
10	Zengin 2023, Turkey ¹⁹	RCT, single-blind, 3-arm	VATS, adults	25/25	NR	20 mL bupivacaine	20 mL bupivacaine	VAS 24 h, morphine, rescue; 24 h	Lower VAS with ESPB; morphine 15.3 vs 19.3 mg
11	Moorthy 2023, Ireland ²¹	RCT, double-blind, two-centre	Minimally invasive thoracic surgery, adults	37/37	NR	US-guided ESP catheter; 20 mL 0.375% levobupivacaine + 0.15% infusion × 48 h	Surgeon-placed thoracoscopic PVB catheter; identical regimen	QoR-15 24/48 h, AUC pain, opioid, CPSP; 3 mo	Higher QoR-15 with ESP; similar pain, opioid and CPSP
12	Zhang L 2023, China ¹³	RCT, double-blind, 3-arm	VATS, adults	37/37	48.5/51.9	Single preoperative ESPB	Single preoperative TPVB	Static NRS 2 h, hypotension, CPSP; 6 mo	TPVB lower early pain; hypotension

									40.5% vs 5.4%
13	Sobhy 2023, Egypt ⁵⁴	RCT, equivalence	VATS, adults	40/40	NR	T5 single-shot	T5 single-shot	Morphine, VAS 0–48 h, block time, satisfaction; 48 h	Equivalent morphine; shorter block time and higher satisfaction with ESPB
14	Andrade Filho 2024, Brazil ¹⁷	RCT, non-inferiority (stopped at interim)	Unilateral lung surgery (mixed approaches), adults	61/59	NR	Continuous ESPB, T5	Continuous PVB, T5	Mean NRS 24 h, analgesic failure, opioid; 24 h	ESPB not non-inferior; higher pain and opioid
15	Abd El-ghaffar 2024, Egypt ⁵⁵	RCT, 3-arm	VATS, adults	35/35	NR	T5; 20 mL 0.5% bupivacaine + adrenaline	T5; 20 mL 0.5% bupivacaine + adrenaline	Et-sevoflurane, fentanyl, VAS; 24 h	Comparable intra- and postoperative analgesia
16	Xu M 2024, China ³¹	RCT, non-inferiority	Paediatric Nuss repair (4–18 y)	34/34	11.7/11.2	Bilateral T5; 0.5 mL/kg 0.25% ropivacaine	Bilateral T5; 0.5 mL/kg 0.25% ropivacaine	NRS 24 h, oral MME, CPSP; 3 mo	ESPB non-inferior; one pneumothorax with TPVB
17	Zhu 2025, China ³⁰	RCT, double-blind, 3-arm, non-	Single-incision VATS, adults	24/25	NR	20 mL 0.5% ropivacaine	20 mL 0.5% ropivacaine	AUC NRS 24 h, opioid, QoR-15; 24 h	ESPB non-inferior; no difference in

		inferiority							opioid or QoR-15
18	Li J 2025, China ¹⁰	RCT, double-blind, 3-arm	VATS, adults	22/24	52.4/49.0	T5; 20 mL 0.5% ropivacaine	T5; 20 mL 0.5% ropivacaine	NRS 0–48 h, OME, dermatomes, block time; 1 mo	TPVB lower early NRS, more dermatomes; two unintended epidural spreads with TPVB
19	Wang LF 2025, China ²⁹	RCT, single-blind, 3-arm	Uniportal VATS, adults	35/28	60.4/54.7	40 mL 0.25% ropivacaine + dexamethasone	30 mL 0.33% ropivacaine + dexamethasone	Total opioid, pain, block-related AEs, cost; 6 mo	No analgesic advantage; block-related AEs 17.9% vs 2.9%
20	Zhao M 2025, China ⁵⁶	RCT, 3-arm	VATS lobectomy, adults	30/30	60.5/60.0	Single preoperative ESPB	Single preoperative TPVB	QoR-15, VAS, sufentanil, GI recovery; 48 h	Comparable QoR-15 and pain
21	Sıvacı 2025, Turkey ⁵⁷	RCT	VATS, adults	49 (total)	18–70 (range)	US-guided ESPB	US-guided TPVB	Analgesics, VAS, SPI/BIS, ABG; NR	ESPB as effective as PVB and easier to perform
22	Adiyeke	RCT,	VATS, adults	30/30	37/40	T4–T5	T4–T5	QoR-15 24 h,	QoR-15 higher

	2026, Turkey ³²	registered			(median)			NRS 0–24 h, MME; 24 h	with PVB (below MCID); pain lower with PVB only at 0 h
23	You 2026, China ³³	RCT, 3-arm	VATS lobectomy, adults	40/40	61.5/61 (median)	T5 + T8	T5 + T8	QoR-15 24 h, VAS rest/cough 1–48 h, AEs; 48 h	Comparable; two extrapleural haematomas with TPVB
24	Sertçakacılar 2022, Turkey ¹⁶	Retrospective cohort	Single-port VATS wedge resection, adults	136/11 4	33.9/30.1	Single-injection ESPB	Single- injection TPVB	24-h morphine, NRS, PONV, LOS; 24 h	Morphine 20.06 vs 11.35 mg; TPVB lower dynamic NRS at 6 and 24 h
25	Durey 2023, France ²⁰	Retrospective cohort, propensity score	VATS/RATS for lung cancer, adults	54/53	67 (median, overall)	ESPB	PVB	NRS 24 h rest/cough, morphine, rehabilitation; 24 h	Lower adjusted pain with ESPB; similar morphine
26	He HZ 2024, China ⁵⁸	Retrospective cohort, PSM	VATS, adults	41/41 (match ed)	NR	US-guided ESPB	Conventional TPVB	VAS, QoR-15, lung function, complications; 48 h	Lower VAS 12– 48 h, higher QoR-15 and fewer

									complications with ESPB
27	Nabil 2026, Egypt‡ ⁵⁹	RCT (extended population)	Paediatric PCNL (2–7 y)	27/28	4.5/4.9	T11; 0.3 mL/kg 0.25% bupivacaine	T10–T11; identical regimen	Time to first rescue, block time; 24 h	Comparable rescue; ESPB faster (4.37 vs 5.05 min)

ABG, arterial blood gas; AE, adverse event; AUC, area under the curve; BIS, bispectral index; CPSP, chronic postsurgical pain; ICNB, intercostal nerve block; LA, local anaesthetic; LOS, length of stay; MME/OME, morphine/oral morphine equivalents; NR, not reported; PCA, patient-controlled analgesia; PCNL, percutaneous nephrolithotomy; PSM, propensity-score matching; QoR-15, Quality of Recovery-15; RATS, robot-assisted thoracoscopic surgery; SPI, surgical plethysmographic index; US, ultrasound. ‡Extended-population trial used only in sensitivity analyses.

Risk of bias and methodological quality

Eight of the 24 RCTs (33.3%) were judged at low overall risk of bias and 16 (66.7%) raised some concerns; none was at high risk. Concerns arose predominantly from domain 2 (unblinded block operators and, in several trials, unblinded patients) and domain 4 (outcome assessors not explicitly blinded for subjective pain scores), followed by domain 5 in trials without accessible registered analysis plans. Two trials were retrospectively registered or stopped at an interim analysis.^{17,37} The three observational cohorts scored 7–8 of 9 NOS stars; the two propensity-score analyses earned full comparability credit, whereas outcome assessment was unblinded in all cohorts.^{16,20,58}



D1 randomisation process; D2 deviations from intended interventions; D3 missing outcome data;
D4 measurement of the outcome; D5 selection of the reported result. + low risk - some concerns x high risk

Figure 1. RoB 2 traffic-light plot for the 24 randomised trials (23 thoracic trials and one extended-population trial).

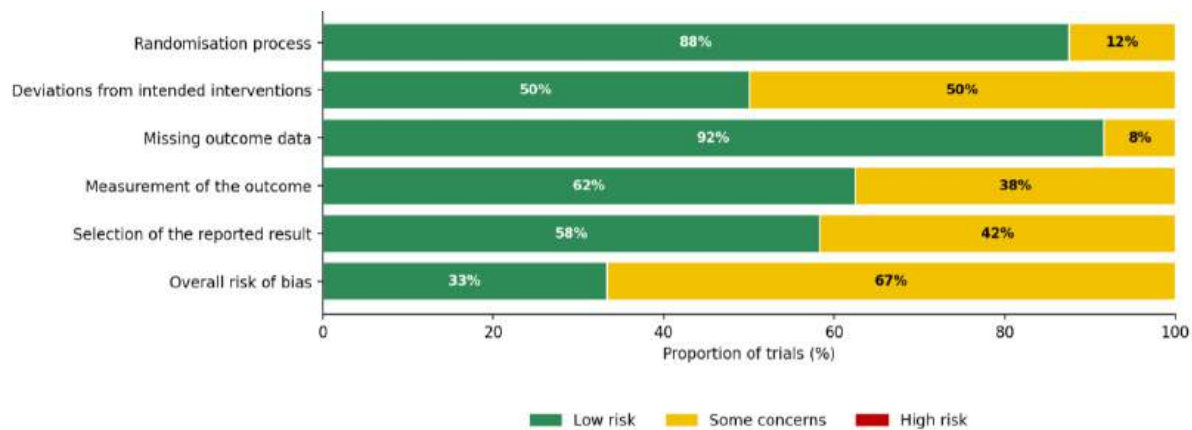


Figure 2. RoB 2 summary plot showing the proportion of trials with low risk, some concerns and high risk in each domain.

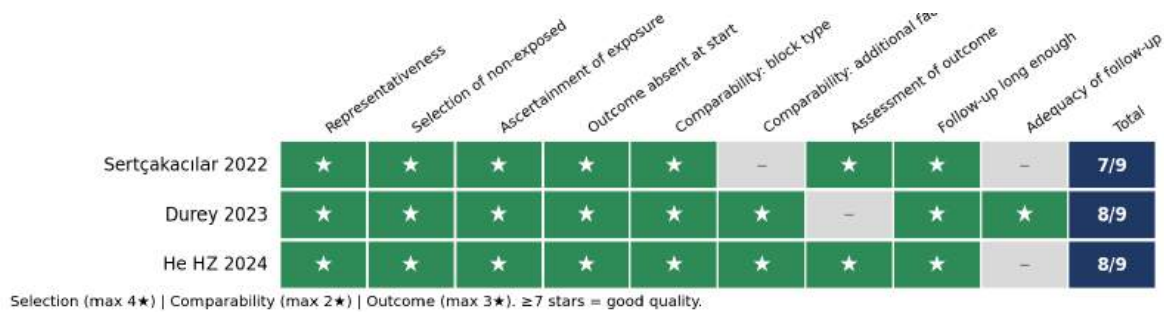


Figure 3. Newcastle–Ottawa Scale assessment of the three observational cohorts. PSM, propensity-score matching.

Table 3. Newcastle–Ottawa Scale scores of observational cohorts

Study	Selection (max 4)	Comparability (max 2)	Outcome (max 3)	Total (max 9)	Quality
Sertçakacılar 2022 ¹⁶	★★★★	★	★★	7	Good
Durey 2023 ²⁰	★★★★	★★ (propensity score)	★★	8	Good
He HZ 2024 ⁵⁸	★★★★	★★ (PSM 1:1)	★★	8	Good

Pain at rest

Nine studies (773 participants) contributed to early rest pain (0–2 h). TPVB yielded significantly lower scores (MD 0.41, 95% CI 0.02–0.81; $p = 0.041$), but with substantial heterogeneity ($I^2 = 84\%$; 95% prediction interval -0.90 to 1.73) and a magnitude below the 1-point MCID. Restricting the analysis to RCTs increased the effect (MD 0.57, 0.08–1.07; $p = 0.023$), whereas omitting the trial by Li and colleagues, in which ESPB produced no measurable dermatomal block, attenuated it to non-significance (MD 0.17, -0.06 to 0.39).^{10,13,32}

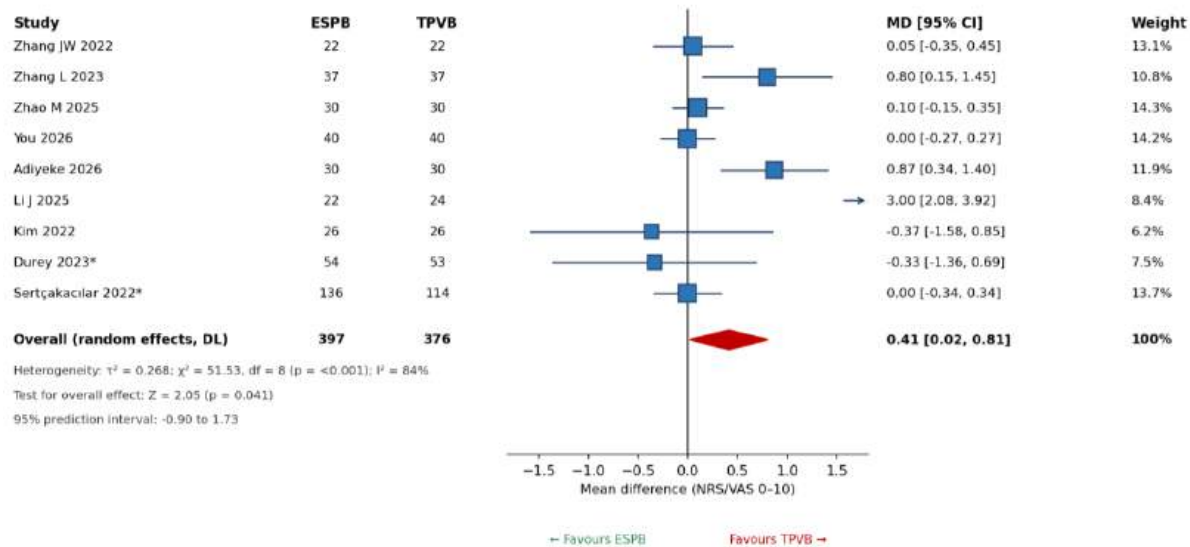


Figure 4. Forest plot of rest pain at 0–2 h. Squares are proportional to study weight; the diamond represents the pooled random-effects estimate. Positive values indicate higher pain with ESPB. *Observational cohort.

The difference was no longer significant at 6–8 h (MD 0.21, -0.15 to 0.57 ; 7 studies; $I^2 = 83\%$) or 12 h (MD 0.09, -0.36 to 0.53 ; 5 studies; $I^2 = 78\%$) (Figures 6 and 7). At 24 h, nine studies (819 participants) showed no difference (MD 0.13, -0.20 to 0.46 ; $I^2 = 80\%$); heterogeneity disappeared when pooling RCTs only (MD 0.04, -0.12 to 0.21 ; $I^2 = 0\%$) (Figure 8). At 48 h, five trials showed a precise null effect without heterogeneity (MD -0.08 , -0.24 to 0.09 ; $I^2 = 0\%$).^{9,16,20,33,53,56}

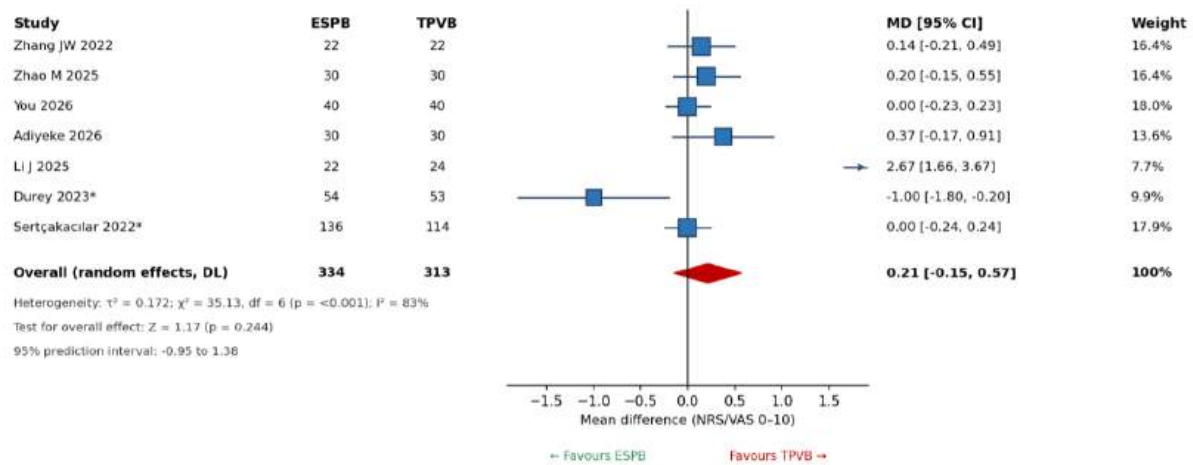


Figure 5. Forest plot of rest pain at 6–8 h. *Observational cohort.

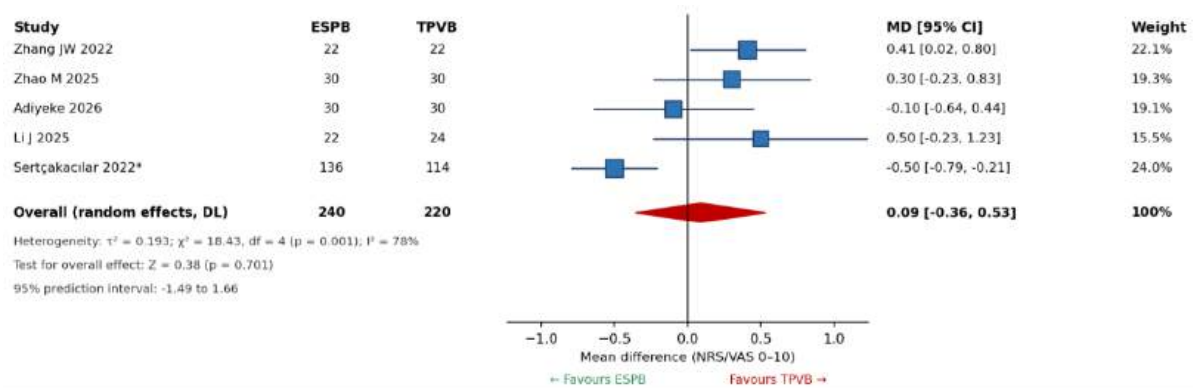


Figure 6. Forest plot of rest pain at 12 h. *Observational cohort.

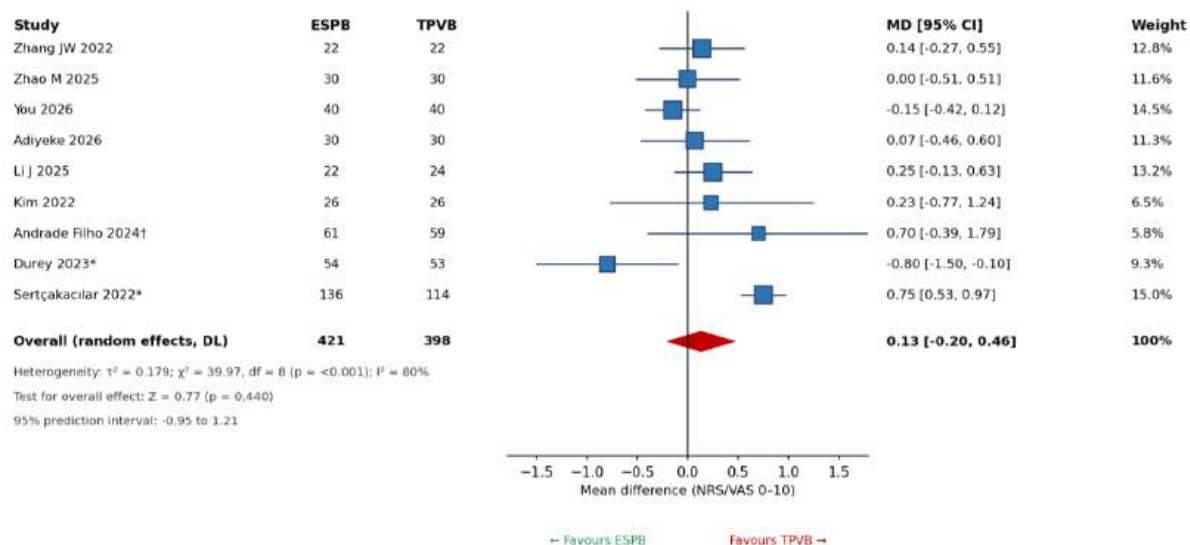


Figure 7. Forest plot of rest pain at 24 h. *Observational cohort; †mixed open/thoracoscopic lung surgery, mean NRS over 24 h.

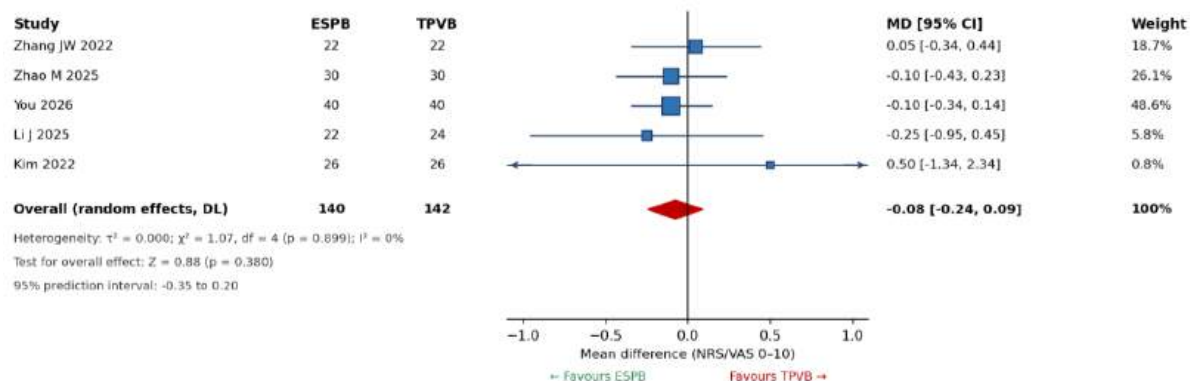


Figure 8. Forest plot of rest pain at 48 h.

Figure integrates these estimates into a temporal trajectory, illustrating a narrow early analgesic gap favouring TPVB that converges towards zero within the first postoperative day for both static and dynamic pain, remaining within the ± 1 -point MCID band at every time point.

Dynamic (coughing) pain

Dynamic pain did not differ at 0–2 h (MD 0.08, -0.36 to 0.51; 6 studies; $I^2 = 73\%$), 6–8 h (MD 0.04, -0.38 to 0.47; 4 studies), 24 h (MD 0.03, -0.66 to 0.73; 4 studies; $I^2 = 91\%$) or 48 h (MD 0.05, -0.16 to 0.26; 2 trials) (Figures 10–12). Among RCTs alone, the early estimate pointed

towards TPVB without reaching significance (MD 0.34, -0.20 to 0.87). The very high heterogeneity at 24 h reflected opposite directions in the two observational cohorts: lower adjusted dynamic pain with ESPB in the propensity-score study and higher pain with ESPB in the single-port cohort.^{13,15,16,20}

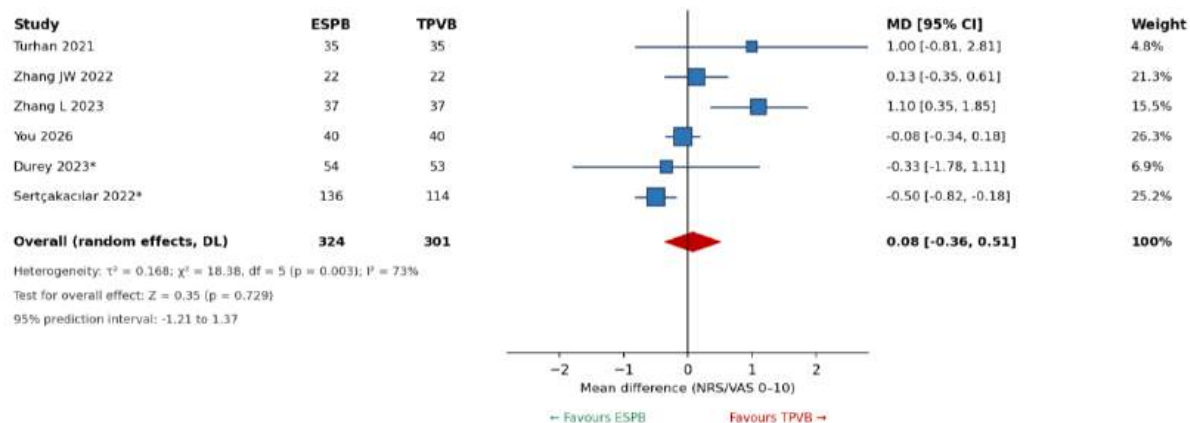


Figure 9. Forest plot of dynamic (coughing) pain at 0–2 h. *Observational cohort.

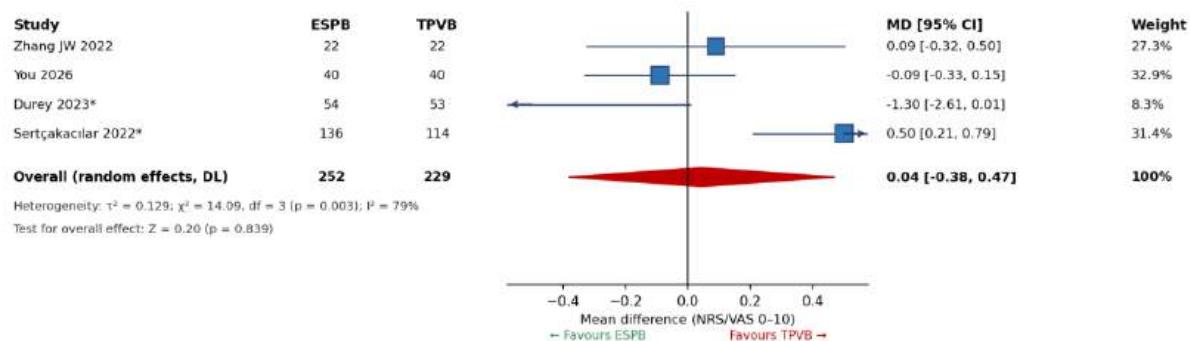


Figure 10. Forest plot of dynamic pain at 6–8 h. *Observational cohort.

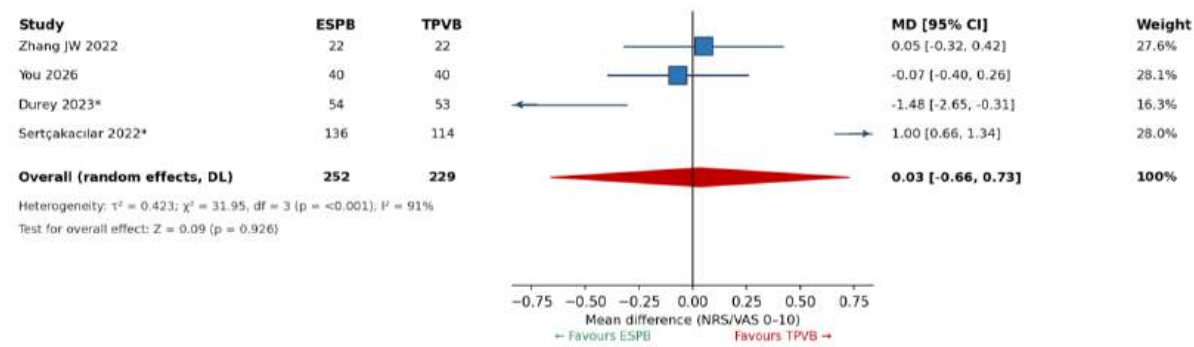


Figure 11. Forest plot of dynamic pain at 24 h. *Observational cohort.

Opioid consumption and rescue analgesia

Ten studies (890 participants) reported 24-h opioid consumption. The pooled SMD of 0.35 (95% CI -0.00 to 0.71 ; $p = 0.051$; $I^2 = 82\%$) indicated a small, borderline opioid-sparing effect of TPVB (Figure 13). The RCT subgroup (SMD 0.28 , -0.05 to 0.61) and observational subgroup (SMD 0.55 , -0.45 to 1.55) did not differ (p for interaction = 0.62). Restricting to adults yielded a significant effect (SMD 0.41 , 0.04 – 0.79 ; $p = 0.029$), whereas excluding the large single-port cohort removed significance (SMD 0.26 , -0.05 to 0.56). In absolute terms, the largest differences were observed with multi-injection TPVB (median morphine 10.5 vs 22 mg) and in the single-port cohort (11.35 vs 20.06 mg), while equivalence was observed with bi-level ESPB or identical intercostal co-blocks.^{14,16,31,37,54}

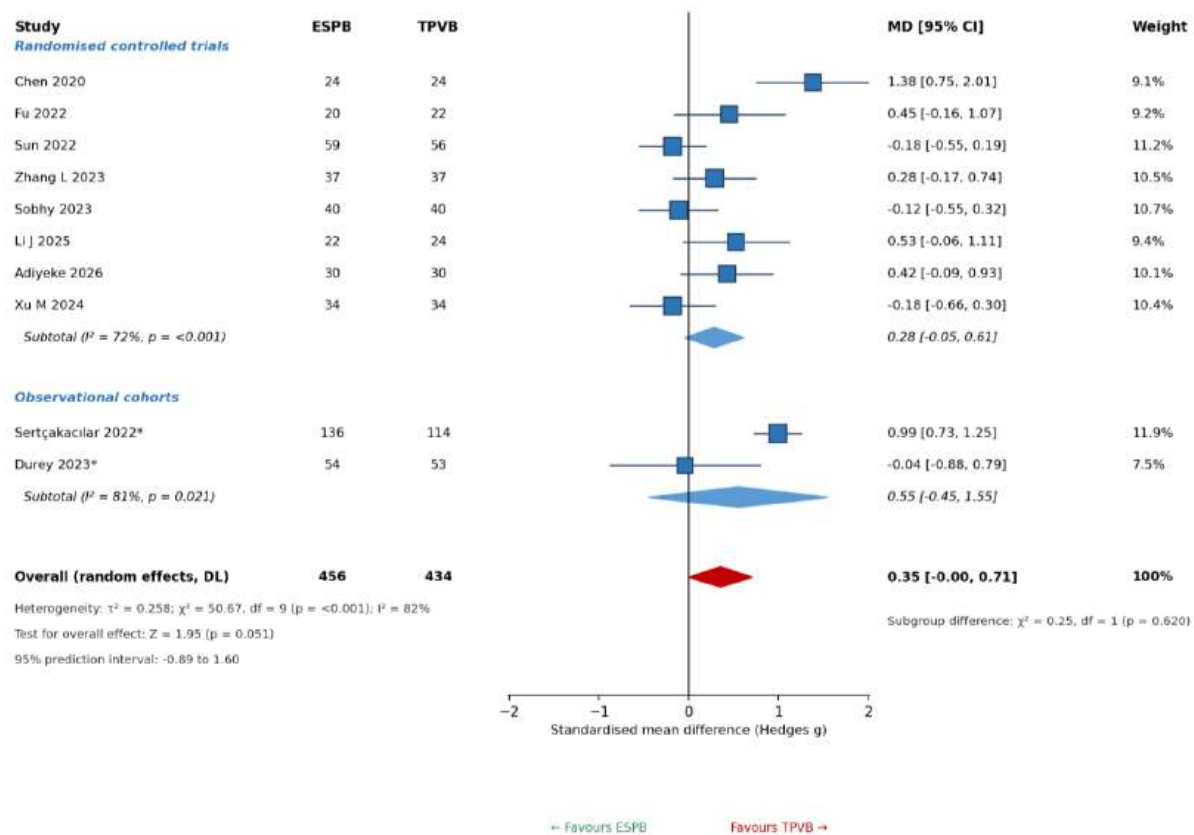


Figure 12. Forest plot of 24-h opioid consumption (Hedges g), subgrouped by study design. Positive values indicate greater opioid use with ESPB. *Observational cohort.

Forty-eight-hour or total opioid consumption (7 trials) showed no significant difference (SMD 0.20, -0.14 to 0.55; $I^2 = 69\%$). The requirement for rescue analgesia (RR 1.21, 0.83–1.77; 6 studies; $I^2 = 40\%$) and the incidence of moderate-to-severe pain at 24 h (RR 1.16, 0.80–1.69; 3 trials; $I^2 = 0\%$) were also comparable. Adding the paediatric percutaneous nephrolithotomy trial did not change the rescue estimate (RR 1.19, 0.87–1.62).^{10,36,59}

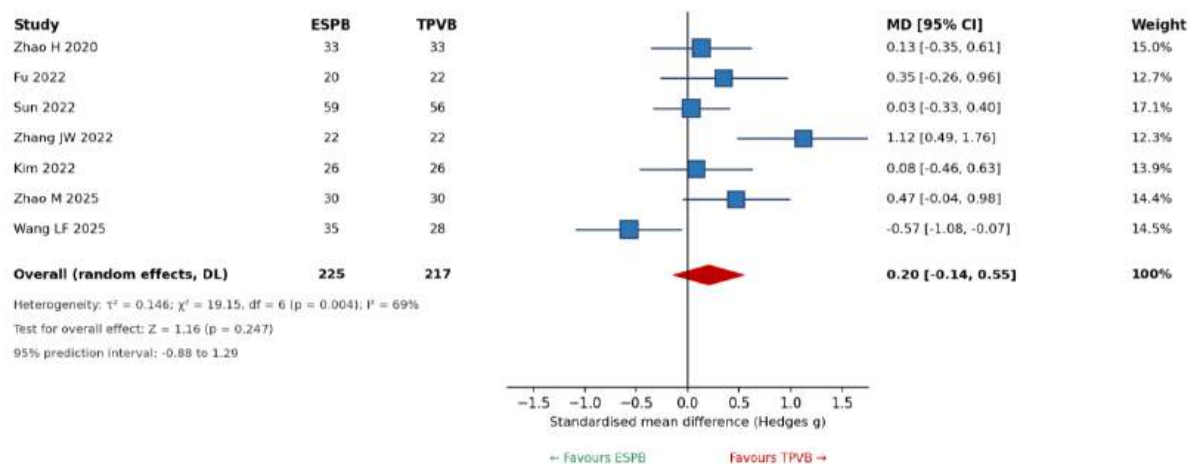


Figure 13. Forest plot of 48-h/total postoperative opioid consumption (Hedges g).

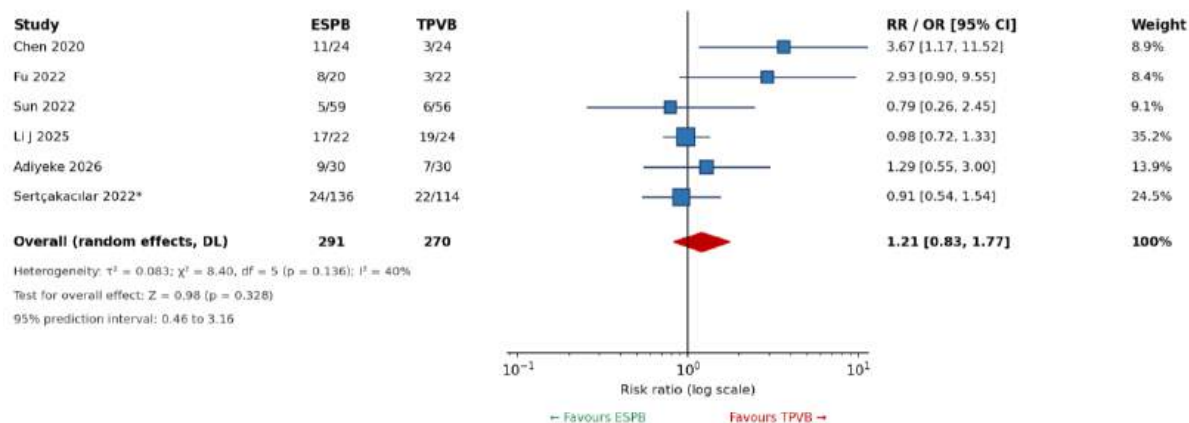


Figure 14. Forest plot of the requirement for rescue analgesia (risk ratio, log scale). *Observational cohort.

Safety outcomes

Block-related complications were reported in eight trials (546 participants), seven of which were estimable. Events occurred in 1 of 276 ESPB patients versus 15 of 270 TPVB patients, comprising pleural puncture, puncture-site and extrapleural haematoma, pneumothorax, unintended epidural spread and haemorrhage or block failure. The Peto OR was 0.15 (95% CI 0.05–0.40; $p < 0.001$; $I^2 = 0\%$), corresponding to an absolute risk difference of approximately 5.2 percentage points

and a number needed to harm of about 19 for TPVB. No local anaesthetic systemic toxicity was reported in either group.^{9,10,29,31,33,37,54}

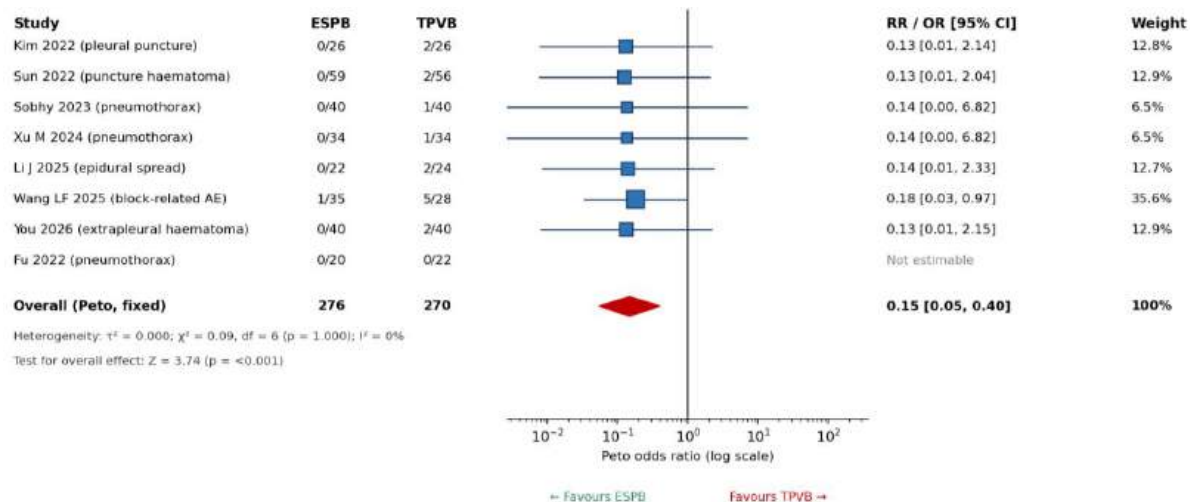


Figure 15. Forest plot of block-related complications (Peto odds ratio, log scale). Studies with zero events in both arms are shown as not estimable.

Hypotension was reported in only three studies, with marked inconsistency (RR 0.60, 0.18–1.97; $I^2 = 73\%$). The largest trial-level contrast was 5.4% with ESPB versus 40.5% with TPVB, while the single-port cohort reported 50.0% versus 64.9% and one trial observed more hypotension with ESPB. Sobhy and colleagues additionally documented significantly lower intraoperative heart rate and blood pressure trends after TPVB without dichotomising hypotension. PONV did not differ (RR 1.00, 0.75–1.34; 10 studies; $I^2 = 0\%$).^{9,13,16,54}

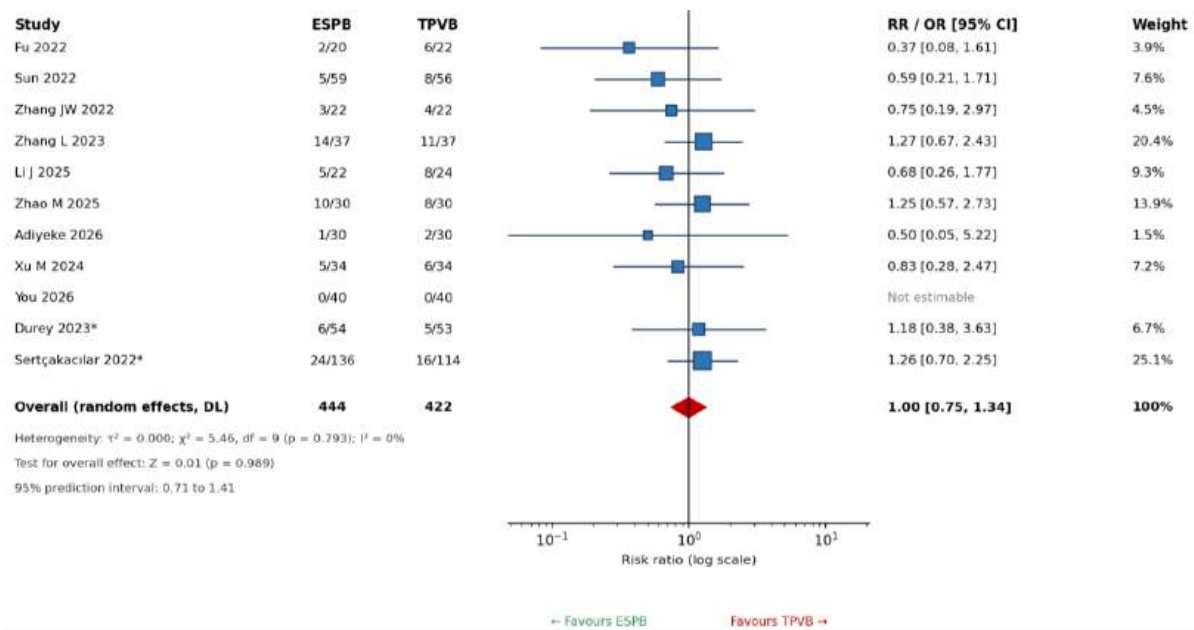


Figure 16. Forest plot of postoperative nausea and vomiting (risk ratio). The double-zero trial is displayed but not pooled. *Observational cohort.

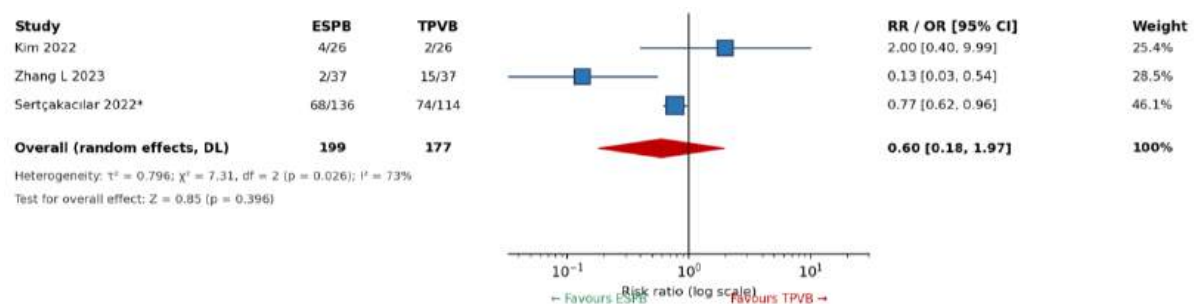


Figure 17. Forest plot of perioperative hypotension (risk ratio). *Observational cohort.

Table 4. Study-level safety events (ESPB vs TPVB, events/patients)

Study	Hypotension	Block-related complication (type)	PONV	LAST
Fu 2022 ³⁶	NR	0/20 vs 0/22 (pneumothorax)	2/20 vs 6/22 (nausea)	NR
Kim 2022 ⁹	4/26 vs 2/26	0/26 vs 2/26 (pleural puncture)	NR	None

Sun 2022 ³⁷	None observed	0/59 vs 2/56 (puncture-site haematoma)	5/59 vs 8/56	None
Zhang JW 2022 ⁵³	NR	NR	3/22 vs 4/22	NR
Zhang L 2023 ¹³	2/37 vs 15/37	NR	14/37 vs 11/37	NR
Sobhy 2023 ⁵⁴	Lower HR/BP trend with TPVB	0/40 vs 1/40 (pneumothorax)	No difference	None
Xu M 2024 ³¹	NR	0/34 vs 1/34 (pneumothorax)	5/34 vs 6/34	None
Li J 2025 ¹⁰	NR	0/22 vs 2/24 (unintended epidural spread)	5/22 vs 8/24	None
Wang LF 2025 ²⁹	NR	1/35 vs 5/28 (haemorrhage, block failure)	Opioid-related AEs 20/35 vs 14/28	NR
Zhao M 2025 ⁵⁶	NR	NR	10/30 vs 8/30	NR
Adiyeke 2026 ³²	NR	Comparable overall complication rates	1/30 vs 2/30	NR
You 2026 ³³	NR	0/40 vs 2/40 (extrapleural haematoma)	0/40 vs 0/40	NR
Sertçakacılar 2022 ¹⁶	68/136 vs 74/114	Postoperative haematoma 4/136 vs 4/114 (not attributed to block)	24/136 vs 16/114	NR
Durey 2023 ²⁰	NR	Bradypnoea 0/54 vs 4/53	6/54 vs 5/53	NR
Nabil 2026† ⁵⁹	Comparable	No pneumothorax or	NR	None

	haemodynamics	toxicity		
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BP, blood pressure; HR, heart rate; LAST, local anaesthetic systemic toxicity; NR, not reported.
‡Extended population.

Procedural efficiency, recovery quality and hospital course

Block performance time tended to be shorter with ESPB (MD -1.59 min, -3.44 to 0.26 ; 3 trials; $I^2 = 93\%$; thoracic trials only MD -2.08 min, -4.51 to 0.35) ; one further trial reported significantly shorter procedure times and higher first-puncture success with ESPB but could not be pooled.^{10,52,54,59} QoR-15 at 24 h did not differ (MD 1.19 points, -4.80 to 7.17 ; $I^2 = 82\%$), reflecting opposite results between a catheter-based trial favouring ESPB and a single-shot trial favouring TPVB.^{21,32,56} Length of hospital stay was comparable across ten studies without heterogeneity (MD -0.13 days, -0.38 to 0.12 ; $I^2 = 4\%$), and the time to first rescue analgesic request did not differ significantly (MD -3.41 h, -8.55 to 1.72).^{10,31}

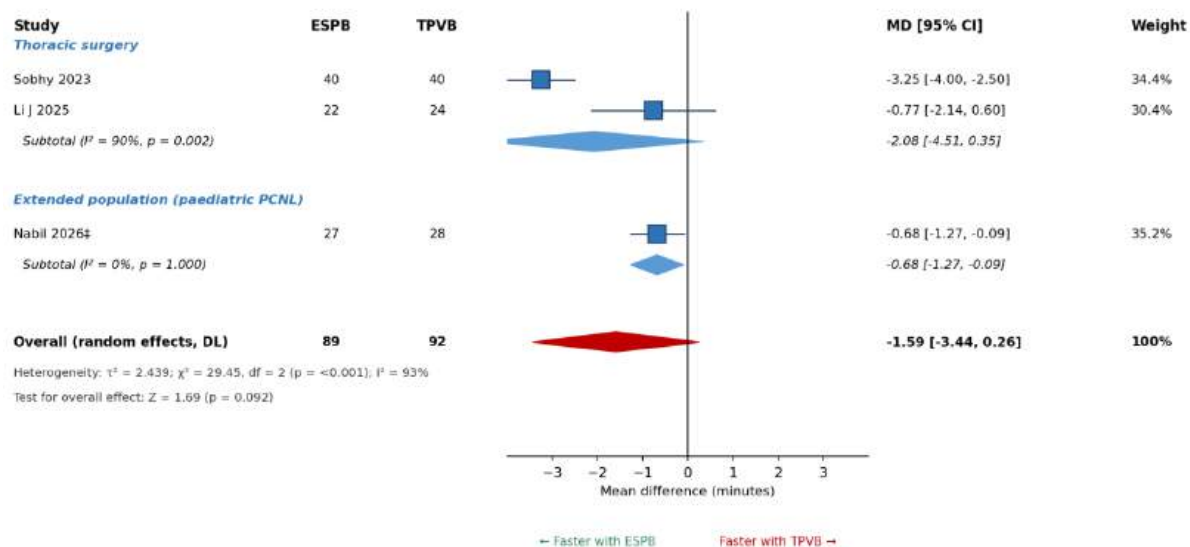


Figure 18. Forest plot of block performance time (minutes), subgrouped by population. ‡Extended population.

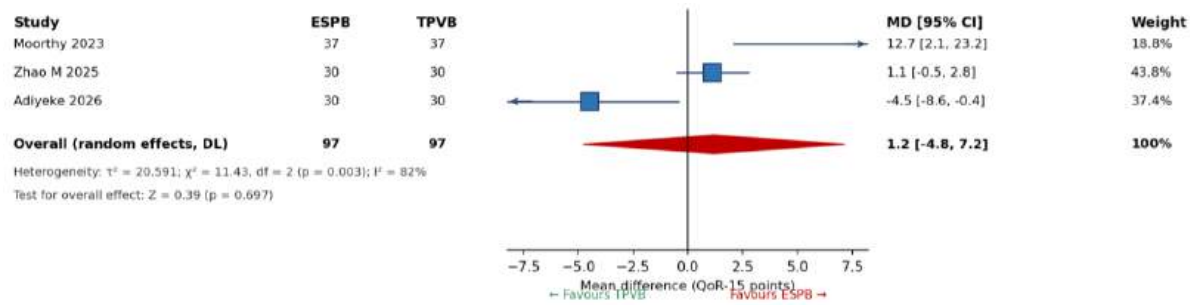


Figure 19. Forest plot of QoR-15 at 24 h. Positive values favour ESPB.

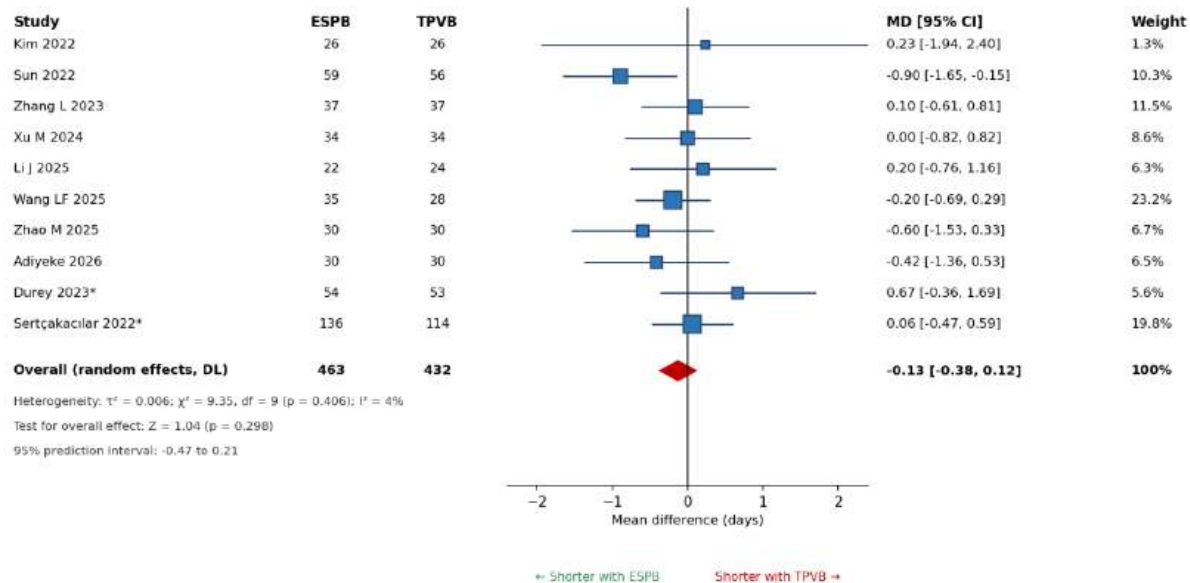


Figure 20. Forest plot of length of hospital stay (days). *Observational cohort.

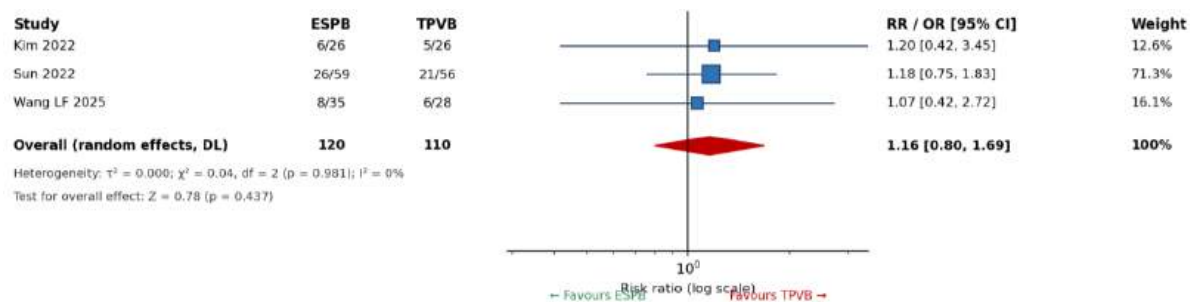


Figure 21. Forest plot of the incidence of moderate-to-severe pain at 24 h (risk ratio).

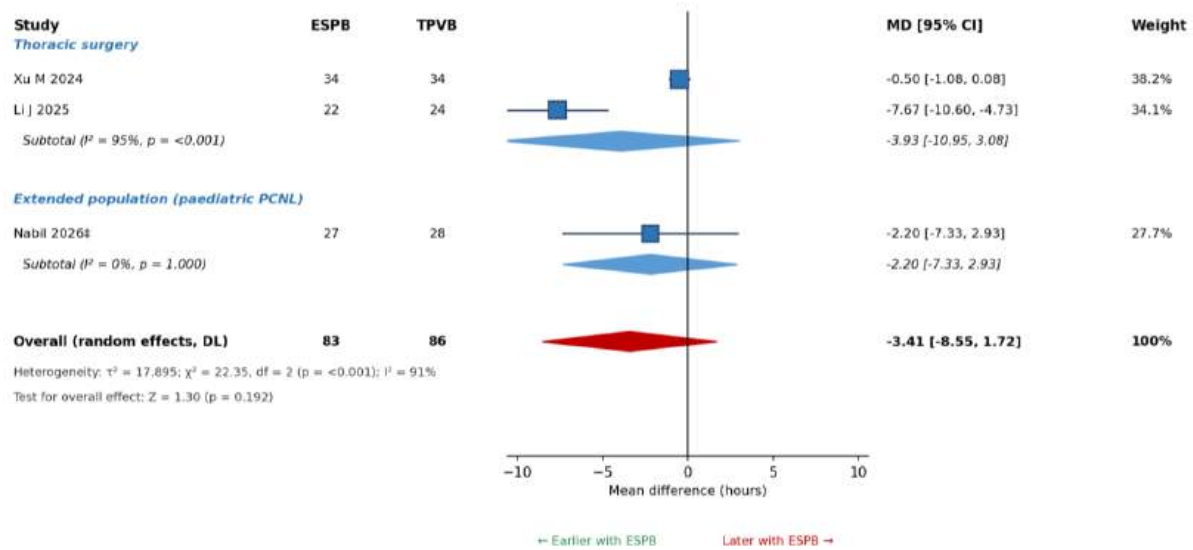


Figure 22. Forest plot of time to first rescue analgesic request (hours), subgrouped by population. ‡Extended population.

Chronic and persistent postsurgical pain

Four trials (267 participants) reported chronic or persistent pain at 1–6 months, with no difference between blocks (RR 0.96, 0.68–1.34; $I^2 = 0\%$). The incidence was high in both arms (approximately 30–40%), underscoring that neither single technique abolishes the transition from acute to persistent pain.^{13,21,29,31}

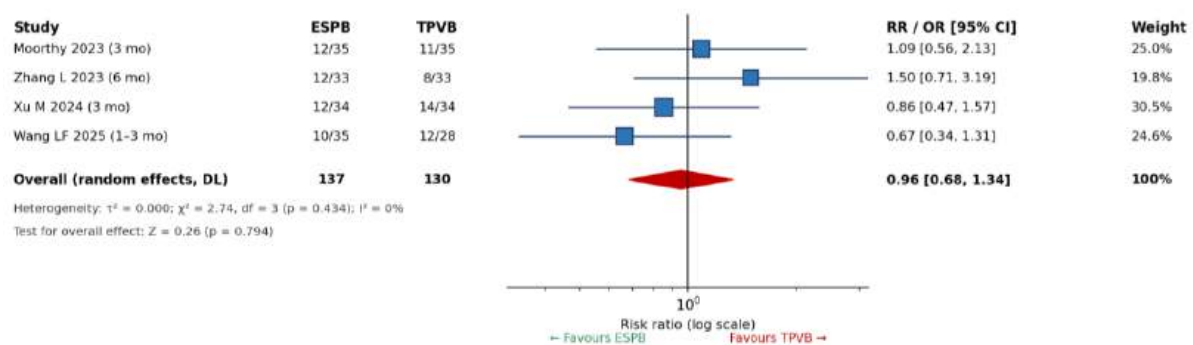


Figure 23. Forest plot of chronic/persistent postsurgical pain (risk ratio).

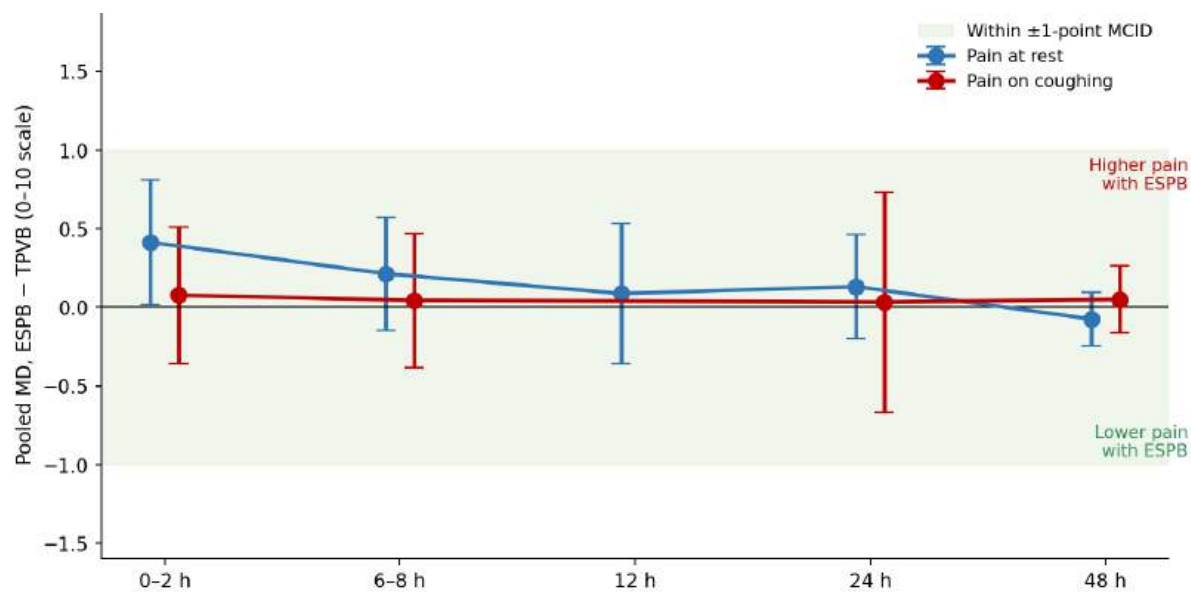


Figure 24. Temporal trajectory (curve) of pooled mean differences in rest and dynamic pain. Error bars denote 95% confidence intervals; the shaded band denotes the ± 1 -point minimal clinically important difference.

Narrative synthesis of non-poolable data

Seven studies could not be pooled, and several pooled studies reported additional non-poolable endpoints. Directionally, two favoured TPVB for analgesia, two favoured ESPB, and the remainder found equivalence; notably, ESPB was associated with lower plasma local anaesthetic concentrations, shorter procedural time and higher first-puncture success.^{12,15,19,30,52,55,57,58}

Table 5. Narrative synthesis of outcomes that could not be pooled

Study	Non-poolable outcome(s)	Principal finding	Direction
Taketa 2019 ¹²	NRS at rest/movement; dermatomes; plasma LA	Lower rest NRS with TPVB at 1, 2, 24 h; fewer parasternal dermatomes but lower plasma levobupivacaine with	TPVB (efficacy); ESPB (pharmacokinetic safety)

		ESPB	
Çiftçi 2020 ⁵²	VAS, fentanyl, block time	Both blocks superior to control; ESPB faster with higher single-puncture success	Neutral; ESPB (procedure)
Zhao H 2020 ¹⁸	Pain scores, QoR-15	Equivalent pain and QoR-15 on POD 1–2	Neutral
Turhan 2021 ¹⁵	24-h morphine, dynamic VAS 24 h	Lower morphine and dynamic pain with TPVB	TPVB
Zengin 2023 ¹⁹	VAS 24 h, morphine	Lower VAS with ESPB; morphine 15.3 vs 19.3 mg	ESPB
Moorthy 2023 ²¹	AUC pain, opioid	No differences	Neutral
Abd El-ghaffar 2024 ⁵⁵	Intraoperative anaesthetic requirement, VAS	Comparable	Neutral
Andrade Filho 2024 ¹⁷	Analgesic failure, opioid	More analgesic failure and opioid with ESPB	TPVB
Zhu 2025 ³⁰	24-h AUC NRS, opioid, QoR-15	Non-inferior (107.8 vs 103.6); no differences	Neutral
Sıvacı 2025 ⁵⁷	Analgesic consumption, VAS, blood gases	Comparable; ESPB easier	Neutral
He HZ 2024 ⁵⁸	VAS 12–48 h, QoR-15, complications	Lower VAS, higher QoR-15, fewer complications with ESPB after PSM	ESPB

Subgroup and sensitivity analyses

The early analgesic advantage of TPVB was consistent in direction across leave-one-out iterations (MD range 0.17 to 0.49) but sensitive to a single trial, whereas the 24-h estimates for rest pain were robust and homogeneous among RCTs. The 24-h opioid estimate remained directionally stable (SMD range 0.25 to 0.42), with statistical significance dependent on the inclusion of individual studies.

Table 6. Subgroup and sensitivity analyses

Analysis	k	Estimate [95% CI]	p	I ²	Interpretation
Rest pain 0–2 h: RCTs only	7	0.57 [0.08, 1.07]	0.023	88%	Advantage of TPVB persists, larger magnitude
Rest pain 0–2 h: excluding Li J 2025	8	0.17 [-0.06, 0.39]	0.151	52%	Loses significance; heterogeneity falls to 52%
Rest pain 24 h: RCTs only	7	0.04 [-0.12, 0.21]	0.618	0%	Null effect, heterogeneity eliminated
Rest pain 24 h: excluding mixed-surgery trial	8	0.09 [-0.25, 0.44]	0.593	82%	Unchanged
Rest pain 24 h: RCTs, thoracoscopic only	6	0.03 [-0.14, 0.20]	0.756	0%	Unchanged (I ² = 0%)
Cough pain 0–2 h: RCTs only	4	0.34 [-0.20, 0.87]	0.218	69%	Direction favours TPVB, not significant
Cough pain 24 h: RCTs only	2	-0.02 [-0.26, 0.23]	0.889	0%	Null, I ² = 0%

Opioid 24 h: adults only	9	0.41 [0.04, 0.79]	0.029	82%	Significant opioid-sparing effect of TPVB
Opioid 24 h: excluding Sertçakacılar 2022	9	0.26 [-0.05, 0.56]	0.101	68%	Attenuated, not significant
Opioid 24 h: RCT subgroup	8	0.28 [-0.05, 0.61]	0.092	72%	Small effect favouring TPVB, not significant
Opioid 24 h: observational subgroup	2	0.55 [-0.45, 1.55]	0.281	81%	Subgroup difference p = 0.62
PONV: RCTs only	8	0.90 [0.63, 1.28]	0.566	0%	Null
Hypotension: RCTs only	2	0.50 [0.04, 7.12]	0.610	84%	Imprecise, inconsistent
Length of stay: RCTs only	8	-0.24 [-0.52, 0.04]	0.089	0%	Trend toward shorter stay with ESPB
Rescue analgesia: adding paediatric PCNL trial	7	1.19 [0.87, 1.62]	0.288	30%	Unchanged
Block time: thoracic trials only	2	-2.08 [-4.51, 0.35]	0.094	90%	Shorter with ESPB, imprecise
Leave-one-out, opioid 24 h	9 each	range 0.25 to 0.42	—	—	Direction stable; significance study-dependent
Leave-one-out, rest pain 0–2 h	8 each	range 0.17 to 0.49	—	—	Direction stable; driven partly by Li J 2025

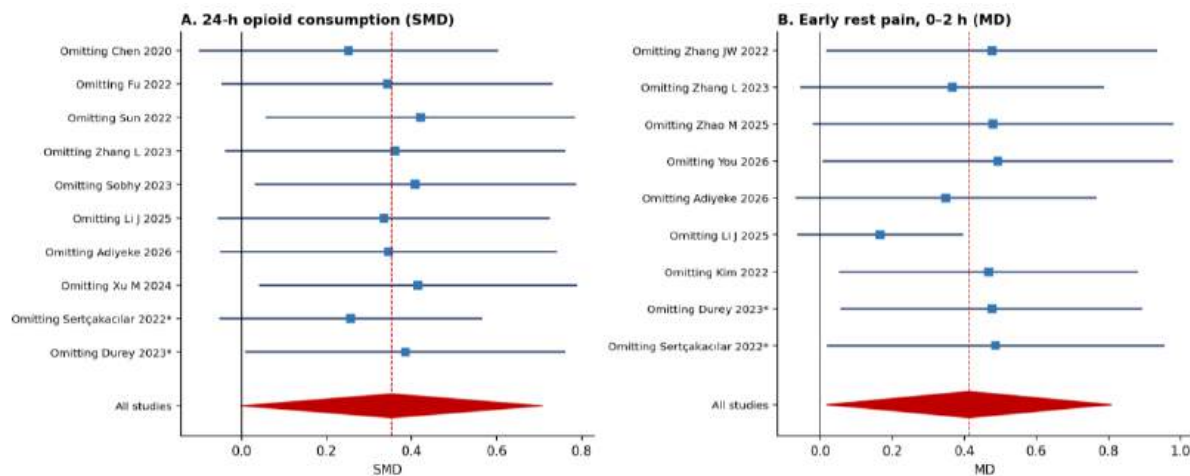


Figure 25. Leave-one-out sensitivity analyses for (A) 24-h opioid consumption and (B) early rest pain. The dashed line marks the overall pooled estimate.

Small-study effects and publication bias

Funnel plots were visually symmetrical for 24-h opioid consumption, rest pain at 24 h and early rest pain, with non-significant Egger's tests ($p = 0.450$, 0.288 and 0.189 , respectively). Asymmetry was detected for PONV (Egger $p = 0.008$), suggesting possible small-study effects or selective reporting of nausea outcomes, and certainty for this outcome was downgraded accordingly.

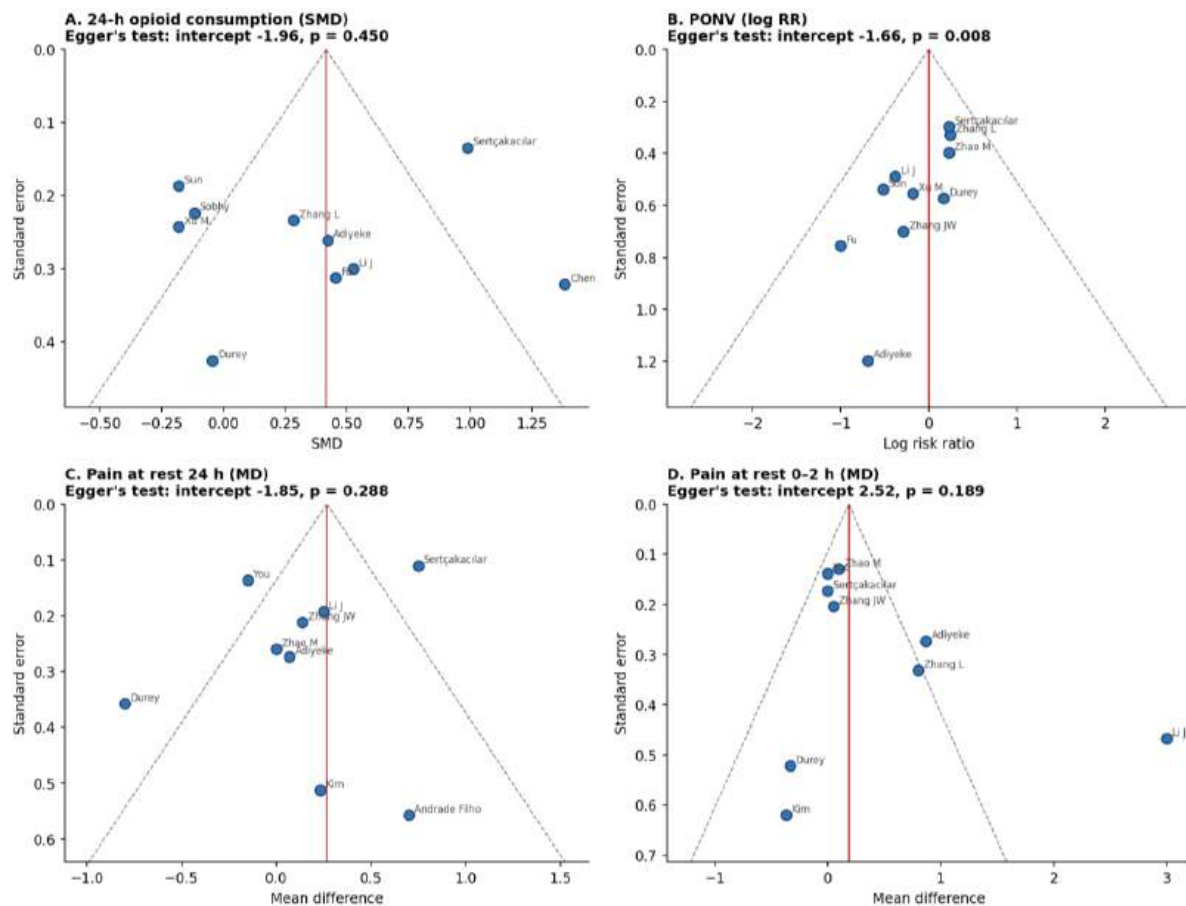


Figure 26. Funnel plots with pseudo-95% confidence limits around the fixed-effect estimate and Egger's regression tests.

Summary of pooled estimates and certainty of evidence

Certainty was moderate for rest and dynamic pain at 48 h, length of stay, block-related complications and CPSP; low for most other pain outcomes, rescue analgesia, hypotension and block time; and very low for opioid consumption, QoR-15 and PONV, chiefly because of risk of bias, inconsistency and imprecision.

Table 7. Summary of pooled estimates (ESPB vs TPVB)

Outcome	k	ESPB	TPVB	Measure	Pooled estimate	p	I ²	Certainty
		n	n					

					[95% CI]			
Pain at rest, 0–2 h (NRS/VAS 0–10)	9	397	376	MD	0.41 [0.02, 0.81]	0.041	84%	Low
Pain at rest, 6–8 h	7	334	313	MD	0.21 [- 0.15, 0.57]	0.244	83%	Low
Pain at rest, 12 h	5	240	220	MD	0.09 [- 0.36, 0.53]	0.701	78%	Low
Pain at rest, 24 h	9	421	398	MD	0.13 [- 0.20, 0.46]	0.440	80%	Low
Pain at rest, 48 h	5	140	142	MD	-0.08 [- 0.24, 0.09]	0.380	0%	Moderate
Pain on coughing, 0–2 h	6	324	301	MD	0.08 [- 0.36, 0.51]	0.729	73%	Low
Pain on coughing, 6–8 h	4	252	229	MD	0.04 [- 0.38, 0.47]	0.839	79%	Low
Pain on coughing, 24 h	4	252	229	MD	0.03 [- 0.66, 0.73]	0.926	91%	Low
Pain on coughing, 48 h	2	62	62	MD	0.05 [- 0.16,	0.646	0%	Moderate

					0.26]			
Opioid consumption, 24 h	10	456	434	SMD	0.35 [-0.00, 0.71]	0.051	82%	Very low
Opioid consumption, 48 h/total	7	225	217	SMD	0.20 [-0.14, 0.55]	0.247	69%	Very low
Rescue analgesia requirement	6	291	270	RR	1.21 [0.83, 1.77]	0.328	40%	Low
Moderate-to-severe pain at 24 h	3	120	110	RR	1.16 [0.80, 1.69]	0.437	0%	Low
PONV	10	444	422	RR	1.00 [0.75, 1.34]	0.989	0%	Very low
Hypotension	3	199	177	RR	0.60 [0.18, 1.97]	0.396	73%	Low
Block-related complications	7	276	270	Peto OR	0.15 [0.05, 0.40]	<0.001	0%	Moderate
Block performance time (min)	3	89	92	MD	-1.59 [-3.44, 0.26]	0.092	93%	Low
Time to first rescue analgesia (h)	3	83	86	MD	-3.41 [-8.55,	0.192	91%	Low

					1.72]			
QoR-15 at 24 h (points)	3	97	97	MD	1.19 [-4.80, 7.17]	0.697	82%	Very low
Length of hospital stay (days)	10	463	432	MD	-0.13 [-0.38, 0.12]	0.298	4%	Moderate
Chronic/persistent postsurgical pain	4	137	130	RR	0.96 [0.68, 1.34]	0.794	0%	Moderate

Positive MD/SMD and RR/OR > 1 indicate a disadvantage of ESPB, except QoR-15 (positive favours ESPB) and block time/time to first rescue (negative favours shorter time with ESPB). Peto OR, Peto one-step odds ratio.

Table 8. GRADE summary of findings

Outcome	Participants (studies)	Relative/absolute effect (95% CI)	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Certainty
Pain at rest, 0–2 h (NRS/VAS 0–10)	773 (9)	MD 0.41 (0.02 to 0.81)	Serious (–1)	Serious (–1)	Not serious	Not serious	Undetected	⊕⊕○○ Low
Pain at rest, 6–8 h	647 (7)	MD 0.21 (-0.15 to 0.57)	Serious (–1)	Serious (–1)	Not serious	Not serious	Not assessable (k < 10)	⊕⊕○○ Low
Pain at rest, 12 h	460 (5)	MD 0.09 (-0.36 to	Serious (–1)	Serious (–1)	Not serious	Not serious	Not assessable	⊕⊕○○ Low

		0.53)					(k < 10)	
Pain at rest, 24 h	819 (9)	MD 0.13 (- 0.20 to 0.46)	Serious (-1)	Serious (-1)	Not serious	Not serious	Undetected	⊕⊕○○ Low
Pain at rest, 48 h	282 (5)	MD -0.08 (-0.24 to 0.09)	Not serious	Not serious	Not serious	Serious (-1)	Not assessable (k < 10)	⊕⊕⊕○ Moderate
Pain on coughing, 0–2 h	625 (6)	MD 0.08 (- 0.36 to 0.51)	Serious (-1)	Serious (-1)	Not serious	Not serious	Not assessable (k < 10)	⊕⊕○○ Low
Pain on coughing, 6–8 h	481 (4)	MD 0.04 (- 0.38 to 0.47)	Serious (-1)	Serious (-1)	Not serious	Not serious	Not assessable (k < 10)	⊕⊕○○ Low
Pain on coughing, 24 h	481 (4)	MD 0.03 (- 0.66 to 0.73)	Serious (-1)	Serious (-1)	Not serious	Not serious	Not assessable (k < 10)	⊕⊕○○ Low
Pain on coughing, 48 h	124 (2)	MD 0.05 (- 0.16 to 0.26)	Not serious	Not serious	Not serious	Serious (-1)	Not assessable (k < 10)	⊕⊕⊕○ Moderate
Opioid consumption, 24 h	890 (10)	SMD 0.35 (-0.00 to 0.71)	Serious (-1)	Serious (-1)	Not serious	Serious (-1)	Undetected	⊕○○○ Very low
Opioid consumption, 48 h/total	442 (7)	SMD 0.20 (-0.14 to 0.55)	Serious (-1)	Serious (-1)	Not serious	Serious (-1)	Not assessable (k < 10)	⊕○○○ Very low
Rescue analgesia	561 (6)	RR 1.21 (0.83 to	Serious (-1)	Not serious	Not serious	Serious (-1)	Not assessable	⊕⊕○○ Low

requirement		1.77)					(k < 10)	
Moderate-to-severe pain at 24 h	230 (3)	RR 1.16 (0.80 to 1.69)	Serious (-1)	Not serious	Not serious	Serious (-1)	Not assessable (k < 10)	⊕⊕○○ Low
PONV	866 (10)	RR 1.00 (0.75 to 1.34)	Serious (-1)	Not serious	Not serious	Serious (-1)	Suspected (-1)	⊕○○○ Very low
Hypotension	376 (3)	RR 0.60 (0.18 to 1.97)	Not serious	Serious (-1)	Not serious	Serious (-1)	Not assessable (k < 10)	⊕⊕○○ Low
Block-related complications	546 (7)	Peto OR 0.15 (0.05 to 0.40)	Not serious	Not serious	Not serious	Serious (-1): few events (16)	Not assessable (k < 10)	⊕⊕⊕○ Moderate
Block performance time (min)	181 (3)	MD -1.59 (-3.44 to 0.26)	Not serious	Serious (-1)	Not serious	Serious (-1)	Not assessable (k < 10)	⊕⊕○○ Low
Time to first rescue analgesia (h)	169 (3)	MD -3.41 (-8.55 to 1.72)	Not serious	Serious (-1)	Not serious	Serious (-1)	Not assessable (k < 10)	⊕⊕○○ Low
QoR-15 at 24 h (points)	194 (3)	MD 1.19 (-4.80 to 7.17)	Serious (-1)	Serious (-1)	Not serious	Serious (-1)	Not assessable (k < 10)	⊕○○○ Very low
Length of hospital stay (days)	895 (10)	MD -0.13 (-0.38 to 0.12)	Serious (-1)	Not serious	Not serious	Not serious	Undetected	⊕⊕⊕○ Moderate

Chronic/persistent postsurgical pain	267 (4)	RR 0.96 (0.68 to 1.34)	Not serious	Not serious	Not serious	Serious (−1)	Not assessable (k < 10)	⊕⊕⊕○ Moderate
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DISCUSSION

Principal findings and their clinical urgency

This systematic review of 27 primary studies (2,015 participants) is, to our knowledge, the first to quantify the efficacy–safety balance between ESPB and TPVB specifically for minimally invasive and uniportal thoracic surgery. Three findings define the trade-off. First, TPVB provided a statistically significant but clinically small analgesic advantage confined to the first two postoperative hours (MD 0.41 points), which vanished by 6 h and was absent at 24 and 48 h, confirming hypotheses H1 and H2. Second, TPVB showed a borderline opioid-sparing effect over 24 h that reached significance only in adult populations, without translating into differences in rescue analgesia, PONV, recovery quality, length of stay or chronic pain. Third, ESPB was associated with an approximately 85% reduction in the odds of block-related complications, confirming H3. Because inadequately treated acute pain after VATS impairs coughing and pulmonary clearance and is the strongest predictor of persistent pain, these findings carry direct implications for enhanced recovery pathways.^{1,3,6}

Mechanistic interpretation of the temporal convergence

The time-limited advantage of TPVB is anatomically coherent. TPVB deposits local anaesthetic directly onto the spinal nerves, dorsal root ganglia and sympathetic chain within the paravertebral space, producing immediate, dense and predictable segmental blockade. ESPB relies on transfascial diffusion from the erector spinae plane through the costotransverse foramina and intertransverse tissues, a process that is slower, volume-dependent and anatomically variable.^{7,11} Trials that mapped sensory loss found a median of six blocked dermatomes after TPVB versus none

after single-shot ESPB at 30 min, fewer parasternal dermatomes after ESPB, and preoperative sensory loss in 78% versus 38% of patients, while magnetic resonance imaging demonstrated injectate confined to the erector spinae plane 30 min after ESPB.^{10,12,13} As diffusion progresses and the multimodal regimen becomes dominant, differences between techniques dissipate, consistent with the homogeneous null estimates at 24–48 h.²⁴

Opioid sparing and patient-centred recovery

An SMD of 0.35 represents a small effect, translating to roughly 3–9 mg of intravenous morphine in the contributing trials. This difference was largest when ESPB was compared with multi-injection TPVB or applied at a single level in single-port surgery, and absent when ESPB was administered at two levels with 30 mL or when both arms received intercostal blocks.^{9,14,16,18,37} Importantly, the opioid difference did not alter PONV or rescue requirements. Recovery quality, the patient-centred anchor of enhanced recovery, did not differ overall; the direction depended on technique, favouring a continuous ESPB catheter over a surgeon-placed paravertebral catheter in one trial and single-shot TPVB in another, with both differences below the 6-point MCID.^{21,32,56} These observations suggest that the delivery mode—catheter, programmed intermittent bolus or multi-level injection—may matter as much as the block target itself.^{60,61}

The safety side of the trade-off

All but one block-related complication in the pooled analysis occurred after TPVB, including pleural puncture, pneumothorax, puncture-site and extrapleural haematoma, and unintended epidural spread.^{9,10,31,33,37,54} In the uVATS trial by Wang and colleagues, block-related adverse events occurred in 17.9% of TPVB versus 2.9% of ESPB recipients, and paediatric data outside thoracic surgery corroborate a higher haematoma rate after paravertebral injection.^{29,62} Sympathectomy-related hypotension could not be confirmed in pooled analysis because of sparse and heterogeneous reporting; nevertheless, the 40.5% versus 5.4% contrast in one double-blind trial, lower haemodynamic trends after TPVB in another and a 29.7% hypotension rate after bilateral TPVB in children undergoing Nuss repair argue for caution in haemodynamically fragile patients.^{13,54,63} The compressible, superficial target of ESPB further favours its use in patients receiving antithrombotic therapy, in line with its distance from neuraxial structures.^{7,9}

Uniportal VATS: specific considerations

Uniportal surgery concentrates trauma in a single intercostal space, which theoretically favours a precisely targeted segmental block. The single-port cohort indeed favoured TPVB for opioid consumption and dynamic pain, whereas a double-blind single-incision trial demonstrated non-inferiority of ESPB.^{16,30} Strikingly, a three-arm uVATS RCT found that neither block reduced opioid consumption compared with intravenous patient-controlled analgesia alone while both increased anaesthesia time and cost, and that TPVB carried more block-related events.²⁹ In addition, surgeon-delivered intercostal nerve blocks under direct vision outperformed ESPB in a multicentre uVATS trial.⁶⁴ In uVATS, therefore, block selection may legitimately be driven by safety, logistics and patient risk profile rather than by marginal analgesic differences.

Comparison with previous systematic reviews and network meta-analyses

Our findings agree with Xiong and colleagues and Pang and colleagues, who reported superior pain relief and lower opioid consumption with PVB in thoracic surgery, but extend them by demonstrating that the advantage is confined to the early period and is offset by safety.^{22,23} The largest prior meta-analysis (25 studies including thoracotomy) found superior analgesia with TPVB at 0–6 h (SMD 0.25), comparable analgesia at 24–48 h and an opioid SMD of 0.42, without differences in PONV or hypotension—estimates closely concordant with ours.²⁴ In children, ESPB shortened the time to first rescue by 0.50 h but avoided the haematoma and pneumothorax observed after PVB.³⁸ Network meta-analyses ranked TPVB first for opioid sparing while considering ESPB a viable alternative.^{25–28} The present review adds a dedicated Peto-based safety synthesis, inclusion of 2025–2026 trials, explicit uVATS and paediatric thoracoscopic data, and GRADE-graded time-stratified outcomes.

Indirect evidence and emerging innovations

Several studies identified during screening did not meet the head-to-head criterion but inform interpretation. Placebo-controlled trials show that single-shot ESPB reduces early pain and improves recovery after VATS, although one multicentre trial found no opioid-sparing benefit, highlighting variability of single-injection fascial plane blocks.^{45,65–67} Continuous ESPB was non-inferior to opioid-based analgesia and to thoracic epidural analgesia, liposomal bupivacaine

prolonged ESPB analgesia to 72 h, and intravenous esketamine provided non-inferior recovery quality to ESPB through mood benefits despite weaker early dynamic analgesia.^{46,47,60,61} Paravertebral injection outperformed the more superficial retrolaminar block, supporting a depth–efficacy gradient, whereas combining TPVB with ESPB reduced chronic pain and rebound pain, and ESPB plus serratus anterior block was non-inferior to PVB.^{13,36,43,44,48} TPVB also improves QoR versus no block, confirming that both techniques are superior to systemic analgesia alone.^{33,68}

Table 9. Indirect evidence retained from screening and the preliminary synthesis (not pooled)

Study	Comparison	Population	Key finding	Relevance to the trade-off
Shim 2020 ⁴⁵	ESPB vs sham	VATS	Lower NRS to 6 h; less PACU rescue	Early efficacy of ESPB vs placebo
Yao 2020 ⁶⁵	ESPB vs saline	VATS	QoR-40 higher by 11 points	Recovery benefit
Liu L 2020 ⁶⁶	ESPB vs no block	Uniportal VATS	24-h sufentanil 32.5 vs 42.8 µg	uVATS-specific efficacy
Clairoux 2024 ⁶⁷	ESPB vs sham	VATS, multicentre	No reduction in 24-h hydromorphone	Variability of single-shot ESPB
Hu 2025 ⁶⁰	Continuous ESPB vs opioid regimen	VATS lung resection	Non-inferior dynamic pain; QoR-15 +11	Catheter-based ESPB
van den Broek 2024 ⁶¹	Continuous ESPB vs TEA	VATS	Non-inferior QoR-15	Alternative to neuraxial analgesia
Shan 2025 ⁴⁷	Liposomal vs plain bupivacaine	VATS lung resection	Lower 72-h rest pain	Prolonged ESPB analgesia

	ESPB			
Liu Z 2026 ⁴⁶	IV esketamine vs ESPB	VATS	Non-inferior QoR-15; ESPB better early cough pain	Systemic alternative when blocks are contraindicated
Wang Q 2021 ⁴⁸	PVB vs retrolaminar block	Uniportal VATS	PVB better analgesia, less nausea	Depth–efficacy gradient
Coppens 2025 ⁶⁴	Surgical ICNB vs ESPB	Uniportal VATS	Lower 12/24-h morphine with ICNB	Surgeon-delivered alternative
He Y 2025 ⁴⁴	TPVB + ESPB vs TPVB	VATS lobectomy	Rebound pain 23.6% vs 47.3%	Combination strategy
Mo 2023 ⁴³	ESPB + SAPB vs PVB	VATS	Non-inferior; higher QoR-15	Fascial plane combination

Clinical recommendations and decision algorithm

When any regional block is contraindicated, systemic multimodal analgesia, optionally with intravenous esketamine or surgeon-placed intercostal blocks, is reasonable.^{46,64} When blocks are feasible, ESPB should be preferred in patients with coagulopathy or antithrombotic therapy, anticipated haemodynamic fragility, spinal deformity, bilateral requirements or limited operator expertise. TPVB remains appropriate when maximal early somatic analgesia and opioid sparing are prioritised and procedural risk is acceptable, and combined TPVB–ESPB may be considered in patients at high risk of CPSP. In all pathways, basic analgesia with paracetamol and NSAIDs or COX-2 inhibitors should be continued, with opioids reserved for rescue.^{6,13,44}

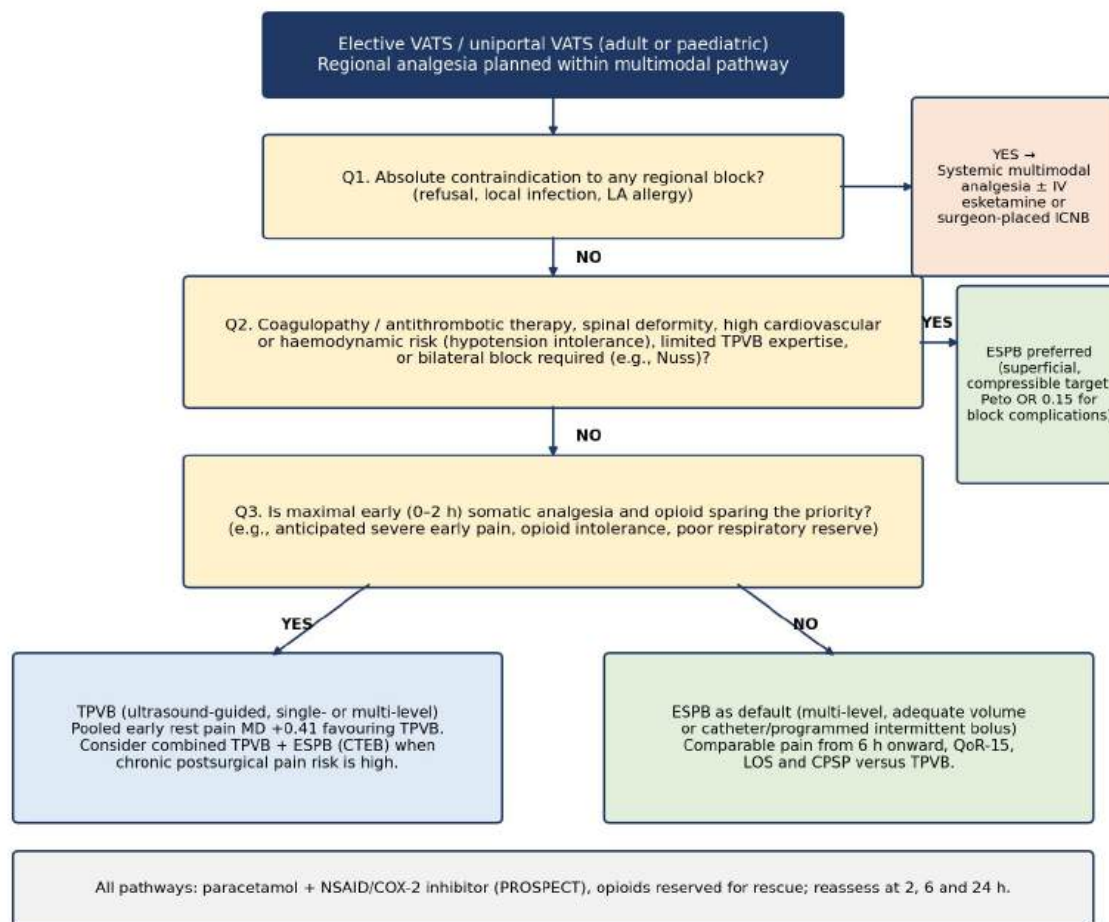


Figure 27. Evidence-informed clinical decision algorithm for block selection in uniportal and multiportal VATS. CTB, combined thoracic paravertebral and erector spinae plane block; ICNB, intercostal nerve block; LA, local anaesthetic.

Strengths

Strengths include a direct head-to-head design, inclusion of both RCTs and comparative primary studies with separate appraisal, time-stratified outcomes, a rare-event safety synthesis, extensive sensitivity analyses and GRADE grading.

Implications for future research

Adequately powered, multicentre, assessor-blinded RCTs restricted to uniportal VATS should compare optimised ESPB (multi-level, adequate volume or catheter with programmed

intermittent bolus) against ultrasound-guided TPVB, using patient-centred primary endpoints such as QoR-15 and core outcome sets for acute and chronic pain. Standardised safety reporting of pleural puncture, haematoma, epidural spread, hypotension and plasma local anaesthetic concentrations, together with cost-effectiveness and 3–6-month CPSP follow-up, is essential.^{4,5,12,21}

CONCLUSION

Compared with TPVB, ESPB provides slightly inferior analgesia only during the first two postoperative hours and possibly a modestly higher 24-h opioid requirement, but equivalent pain from 6 h onward, comparable rescue analgesia, PONV, recovery quality, length of stay and chronic pain, and substantially fewer block-related complications. For uniportal and multiportal VATS, ESPB therefore represents a safer and analgesically comparable default option, whereas TPVB may be reserved for patients in whom maximal early analgesia is prioritised and procedural risk is acceptable. Large, blinded, uVATS-specific trials are required to raise the certainty of these conclusions.^{6,24}

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