Original Research

HEMODYNAMIC STABILITY AND POSTOPERATIVE ANALGESIC OUTCOMES OF ULTRASOUND-GUIDED ERECTOR SPINAE PLANE BLOCK VERSUS THORACIC EPIDURAL ANALGESIA IN MAJOR ABDOMINAL SURGERIES: A COMPARATIVE OUTCOME ANALYSIS

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ABSTRACT

Background: Thoracic epidural analgesia (TEA) is the reference standard for pain control after major abdominal surgery but is limited by sympathetic blockade, hypotension and a defined complication profile. The ultrasound-guided erector spinae plane block (ESPB) is a less invasive interfascial plane alternative. We compared the two techniques for intraoperative haemodynamic stability and postoperative analgesia.

Methods: Seventy adults undergoing elective major open abdominal surgery were randomized to bilateral continuous ESPB (Group E, n = 35) or TEA (Group T, n = 35) within a multimodal regimen. Co-primary outcomes were intraoperative hypotension and vasopressor requirement, and Numeric Rating Scale (NRS) pain scores over 48 h. Secondary outcomes included 24-h opioid consumption, adverse events, time to ambulation and length of stay.

Results: Resting pain scores were comparable; TEA produced lower dynamic scores (significant at 4 h), lower 24-h opioid consumption (16.2 vs 19.6 mg, $p = 0.039$) and longer time to first rescue. Intraoperative hypotension (17.1% vs 42.9%, $p = 0.019$), vasopressor use (14.3% vs 40.0%, $p = 0.017$) and urinary retention (2.9% vs 22.9%, $p = 0.027$) were lower with ESPB, which also enabled earlier ambulation (18.2 vs 24.6 h, $p < 0.001$).

Conclusion: ESPB provides analgesia approaching that of TEA after major abdominal surgery with greater haemodynamic stability and fewer side effects, and is an effective alternative within enhanced-recovery pathways.

Keywords: Erector Spinae Plane Block, Thoracic Epidural Analgesia, Abdominal Surgery, Haemodynamic Stability, Postoperative Analgesia, Regional Anaesthesia.

INTRODUCTION

Major abdominal surgery is associated with intense postoperative pain that, if poorly controlled, drives the surgical stress response, impairs pulmonary function, delays mobilization and bowel recovery, and increases morbidity, length of stay and cost [1,2]. Effective analgesia is therefore a central pillar of perioperative care and of enhanced recovery after surgery (ERAS) programmes, where pain-free early ambulation and rapid return of gastrointestinal function are explicit goals [2,3].

For several decades, thoracic epidural analgesia (TEA) has been regarded as the reference standard for both open and selected laparoscopic abdominal procedures [3,4].

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By producing a segmental neuraxial block, TEA attenuates the neuroendocrine and metabolic stress response, provides excellent static and dynamic analgesia, reduces pulmonary complications and may shorten the duration of postoperative ileus [4,5]. These benefits, however, are coupled with well-recognized drawbacks. Sympathetic blockade frequently produces hypotension—reported in up to a third of patients—often requiring fluid loading and vasopressors, while urinary retention, motor weakness, technical failure rates approaching 30%, and rare but catastrophic complications such as epidural haematoma and abscess further constrain its use [4,6,7]. TEA is also contraindicated in coagulopathy and demands awake positioning and intensive monitoring [6,7]. In the ERAS era, a growing body of evidence questions whether the historical risk–benefit balance still favours routine epidural use [5,8].

This uncertainty has stimulated interest in fascial plane blocks that can reproduce the analgesic efficacy of TEA with a wider safety margin. The erector spinae plane block (ESPB), first described by Forero and colleagues in 2016 for thoracic

neuropathic pain, involves ultrasound-guided injection of local anaesthetic into the interfascial plane between the erector spinae muscle and the tip of the transverse process [9]. The injectate spreads in a cranio-caudal and paravertebral direction, and cadaveric and clinical studies suggest its analgesic action arises from a combination of paravertebral and epidural spread, anterior diffusion to the ventral and dorsal rami, and systemic absorption of local anaesthetic, conferring both somatic and visceral analgesia [10,11,12]. Because the injection point lies well away from the neuraxis and major vessels, the ESPB is technically straightforward, can be performed under minimal sedation, and carries a low complication risk; it has consequently been promoted as a versatile "plan A" block applicable from cervical to lumbar levels [11,13].

Randomized trials and meta-analyses confirm that ESPB lowers pain scores and opioid consumption after a range of thoracic and abdominal operations when compared with placebo or with the transversus abdominis plane block [14,15,16,17]. Direct comparisons with TEA, however, remain relatively scarce, are concentrated in thoracic and cardiac surgery, and yield mixed conclusions—generally describing comparable analgesia with greater haemodynamic stability for the ESPB [18,19,20,21]. Evidence in the specific setting of major abdominal surgery, where the visceral component of pain is prominent and haemodynamic disturbance from neuraxial block is clinically important, is limited [16,22]. The present study was designed to address this gap by comparing ultrasound-guided ESPB with TEA in patients undergoing major abdominal surgery, with intraoperative haemodynamic stability and postoperative analgesic outcomes as co-primary endpoints.

MATERIALS AND METHODS

Study design, ethics and registration

This prospective, randomized, comparative study was conducted in the Department of Anaesthesiology of a tertiary-care teaching hospital over an 18-month period. The protocol was approved by the Institutional Ethics Committee (approval number [INSERT IEC APPROVAL No.]) and prospectively registered with the Clinical Trials Registry – India (registration number [INSERT CTRI No., e.g. CTRI/YYYY/MM/NNNNNN]). The conduct of the study conformed to the principles of the Declaration of Helsinki, and written informed consent was obtained from every participant. Reporting follows the CONSORT recommendations for randomized trials, and the flow of participants is shown in Figure 1 [23].

Participants

Adults aged 18–65 years, of American Society of Anesthesiologists (ASA) physical status I–III, scheduled for elective major open abdominal surgery (gastrointestinal, hepatobiliary, urological and gynaecological-oncological laparotomies through a midline or subcostal incision) were eligible. Exclusion criteria were patient refusal, body mass index >35 kg/m^2, known allergy to local anaesthetics, coagulopathy or anticoagulant therapy, local infection at the injection site, chronic opioid use, significant hepatic or renal impairment, pregnancy, and any contraindication to neuraxial block [6,7].

Randomization and blinding

Seventy patients were allocated in a 1:1 ratio to Group E (ESPB) or Group T (TEA) using a computer-generated random sequence concealed in sequentially numbered opaque sealed envelopes opened immediately before block performance. Because the two interventions are technically distinct, the anaesthesiologist performing the block could not be blinded; however, the surgeon, the outcome assessor recording pain and haemodynamic data, and the patient were unaware of group allocation. All blocks were performed by anaesthesiologists experienced in both techniques.

Sample size

Sample size was estimated for both co-primary outcomes using G*Power v3.1.9.7 (Heinrich-Heine-Universität, Düsseldorf, Germany). For the analgesic co-primary outcome, detecting a clinically important difference of 1.0 point on the NRS with an assumed standard deviation of 1.4, at a two-sided α of 0.05 and power of 80% (independent-samples t test), required 31 patients per group. For the haemodynamic co-primary outcome, the assumed contrast in the incidence of intraoperative hypotension was derived from prior literature: neuraxial/epidural techniques are associated with hypotension in approximately 33–40% of patients [4,6,24], whereas ESPB and related fascial plane blocks report incidences of roughly 10–15% [18,19]. Using a two-proportion comparison (40% vs 10–15%) at the same α and power, 29–32 patients per group were required. The larger estimate (32 per group) was adopted and inflated by approximately 10% to allow for dropouts and technical (block) failures, giving a final enrolment of 35 patients per group. Because robust head-to-head data in major abdominal surgery were unavailable, these effect-size assumptions were necessarily borrowed from adjacent surgical populations; the first 10 recruited patients were therefore treated as an internal pilot to confirm the feasibility of block performance and the plausibility of these estimates before completing recruitment. This limitation is acknowledged in the Discussion.

Block technique and rationale for block level

In Group T, a thoracic epidural catheter was inserted at the T8–T10 interspace by a loss-of-resistance technique before induction; a test dose was followed by 8–10 mL of 0.125% bupivacaine, with an intraoperative and postoperative infusion of 0.0625–0.125% bupivacaine plus fentanyl 2 µg/mL at 4–8 mL/h. In Group E, a bilateral ultrasound-guided ESPB was performed at the **T8** level with the patient sitting or in the lateral position; after identifying the transverse process and erector spinae muscle with a linear or curvilinear probe, 20 mL of 0.25% bupivacaine was deposited deep to the muscle on each side, and catheters were threaded for intermittent top-ups of 15 mL of 0.125% bupivacaine every 6 h [9,11].

A single, standardized T8 injection level was chosen deliberately. Because local anaesthetic deposited in the erector spinae plane spreads extensively in a cranio-caudal direction—typically covering several dermatomes above and below the injection point—a mid-thoracic T8 injection with a relatively high volume (20 mL per side) is positioned to cover the T6–L1 dermatomes that supply most upper and lower abdominal incisions, providing a pragmatic and reproducible technique across the heterogeneous case mix [10,11,16]. Standardizing the level also removed injection height as a confounder between groups. We recognize that some authors favour a lower (T10–L1) injection for purely lower-abdominal or pelvic procedures, and this is addressed as a limitation.

Anaesthesia, haemodynamic management and vasopressor protocol

General anaesthesia was standardized: induction with intravenous fentanyl, propofol and a non-depolarizing neuromuscular blocker, and maintenance with an oxygen–air–sevoflurane mixture titrated to clinical depth. Intraoperative hypotension—defined as a fall in mean arterial pressure (MAP) below 65 mmHg or by more than 20% from baseline—was managed by a stepwise protocol: a 250-mL balanced-crystalloid bolus, followed, if hypotension persisted, by intravenous ephedrine in 6-mg boluses; when hypotension was accompanied by an adequate or high heart rate, intravenous phenylephrine 50–100 µg boluses were used instead. A phenylephrine infusion (25–50 µg/min) was started only if boluses failed to restore MAP. Bradycardia (heart rate <50 beats/min) was treated with atropine 0.6 mg. The number of patients requiring each vasopressor and the cumulative dose per treated patient were recorded (Table 2). Postoperatively all patients received multimodal analgesia (regular paracetamol and a non-steroidal anti-inflammatory agent), with intravenous morphine as rescue analgesia titrated to an NRS ≥4 [2].

Definition of block failure / inadequate block

A block was classified as failed or inadequate according to predefined criteria. For TEA, failure was defined as inability to place the catheter after three attempts, a negative or asymmetrical response to the test dose, absence of a demonstrable bilateral sensory block to cold within 15 minutes of the loading dose, or a resting NRS >6 in the immediate postoperative period despite an appropriate epidural bolus, necessitating conversion to systemic analgesia. For ESPB, failure was defined as inability to visualize correct interfascial spread of local anaesthetic on ultrasound, or a resting NRS >6 within 30 minutes of block completion requiring rescue analgesia beyond the protocol. Patients with a failed block were retained in their allocated group for intention-to-treat analysis and supplemented with systemic analgesia.

Outcome measures

The co-primary outcomes were intraoperative haemodynamic stability—the incidence of hypotension, vasopressor requirement and the lowest recorded MAP—and postoperative pain intensity on an 11-point NRS (0 = no pain, 10 = worst imaginable) at rest and on movement at 0, 2, 4, 8, 12, 24 and 48 h. Secondary outcomes were cumulative 24-h opioid consumption (intravenous morphine equivalents), time to first rescue analgesia, block performance time, block failure, postoperative nausea and vomiting (PONV), urinary retention, time to first ambulation, time to first flatus, patient satisfaction (0–10) and hospital length of stay.

Statistical analysis

Data were analysed with standard statistical software. Normality was assessed with the Shapiro–Wilk test; normally distributed variables are presented as mean ± standard deviation and compared with the independent-samples t test, and non-normal variables as median (interquartile range) compared with the Mann–Whitney U test. Categorical variables are reported as frequency (percentage) and compared with the chi-square or Fisher exact test. Repeated pain and haemodynamic measurements were analysed with repeated-measures analysis of variance. A two-sided p value <0.05 was considered significant.

RESULTS

Of 78 patients screened, 70 were randomized and all completed the study and were analysed (Group E = 35, Group T = 35); the participant flow is summarized in Figure 1. The groups were well matched for demographic and surgical characteristics, including the distribution of

individual procedures and incision types, with no significant differences (Table 1).

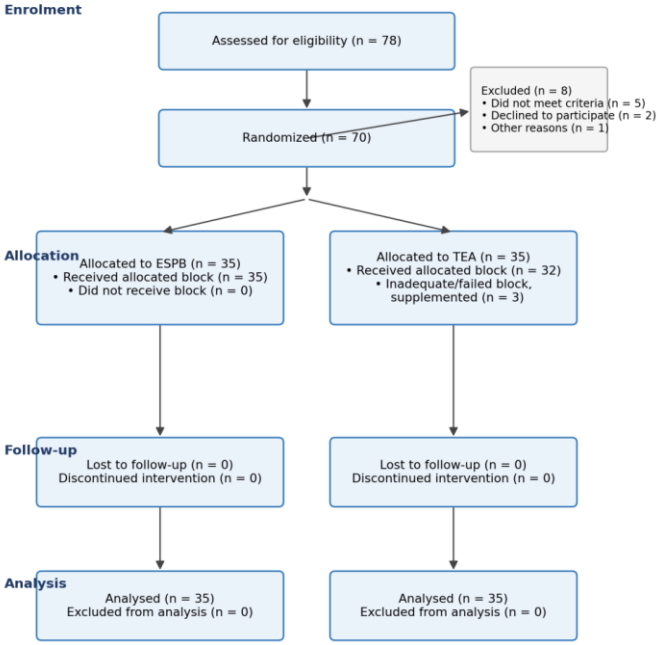

Figure 1. CONSORT flow diagram of participant enrolment, allocation, follow-up and analysis.

Table 1. Demographic characteristics and breakdown of surgical procedures by group.

Variable	Group E (ESPB) (n = 35)	Group T (TEA) (n = 35)	p value
Age (years), mean ± SD	48.3 ± 11.2	50.1 ± 10.6	0.49
Sex (male / female)	19 / 16	17 / 18	0.63
BMI (kg/m²), mean ± SD	25.8 ± 3.4	26.3 ± 3.1	0.52
ASA status (I / II / III)	12 / 16 / 7	10 / 17 / 8	0.84
Duration of surgery (min)	182 ± 41	188 ± 46	0.57
Surgical procedure, n (%)			
Hepatobiliary (e.g. hepatectomy, Whipple)	8 (22.9)	7 (20.0)	0.77
Upper gastrointestinal (e.g. gastrectomy)	6 (17.1)	6 (17.1)	1.00
Colorectal	9 (25.7)	10 (28.6)	0.79
Urological (e.g. nephrectomy, cystectomy)	6 (17.1)	5 (14.3)	0.74
Gynaecological-oncological	6 (17.1)	7 (20.0)	0.76
Region and incision			
Upper / lower abdominal (n)	20 / 15	18 / 17	0.63
Midline / subcostal incision (n)	27 / 8	28 / 7	0.77

Haemodynamic stability

Baseline MAP was similar between groups. After block placement and induction, MAP fell more steeply and remained lower in Group T, reaching a nadir between 30 and 60 min, whereas Group E maintained near-baseline pressures throughout surgery (Figure 2). The mean lowest intraoperative MAP was higher in Group E (76.2 ± 7.1 mmHg) than in Group T (66.4 ± 8.3 mmHg, $p < 0.001$). Intraoperative hypotension occurred in 6 patients (17.1%) in Group E versus 15 (42.9%) in Group T ($p = 0.019$). Vasopressor support was required in 14.3% versus 40.0% ($p = 0.017$): ephedrine was given to 4 versus 10 patients and phenylephrine to 2 versus 6, with lower cumulative doses in the ESPB

group. Bradycardia was numerically less frequent with ESPB (Table 2).

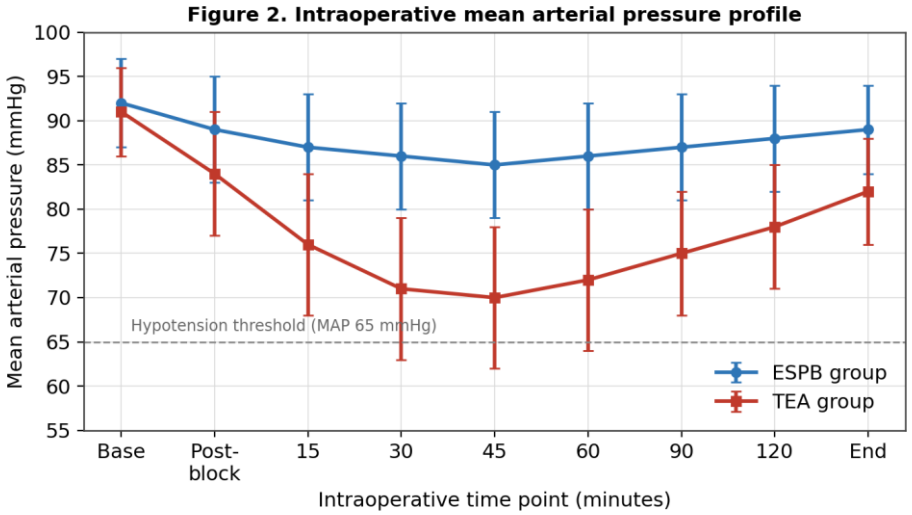

Figure 2. Intraoperative mean arterial pressure (MAP) at sequential time points (mean ± SD). The ESPB group maintained MAP close to baseline, whereas the TEA group showed a sustained reduction during the first operative hour.

Table 2. Intraoperative haemodynamic outcomes and vasopressor use.

Outcome	Group E (ESPB)	Group T (TEA)	p value
Lowest intraoperative MAP (mmHg)	76.2 ± 7.1	66.4 ± 8.3	<0.001
Intraoperative hypotension, n (%)	6 (17.1)	15 (42.9)	0.019
Any vasopressor required, n (%)	5 (14.3)	14 (40.0)	0.017
Ephedrine, patients / cumulative dose (mg)*	4 / 9.0 ± 3.0	10 / 13.8 ± 5.5	0.04
Phenylephrine, patients / cumulative dose (µg)*	2 / 100 ± 40	6 / 220 ± 90	0.05
Bradycardia (atropine), n (%)	2 (5.7)	6 (17.1)	0.13
Intraoperative fentanyl (µg)	142 ± 38	128 ± 34	0.11

*Cumulative dose expressed as mean ± SD among treated patients only.

Postoperative analgesia

Pain control was effective in both groups over 48 h (Figure 3). Resting NRS scores did not differ significantly at any time point. Dynamic (on-movement) scores were consistently lower in Group T, reaching statistical significance at 4 h (4.2 ± 1.4 vs 3.5 ± 1.3, p = 0.04) and approaching significance at several adjacent points (Table 3). Both groups maintained mean dynamic scores below 4.5 and resting scores below 3.2 throughout.

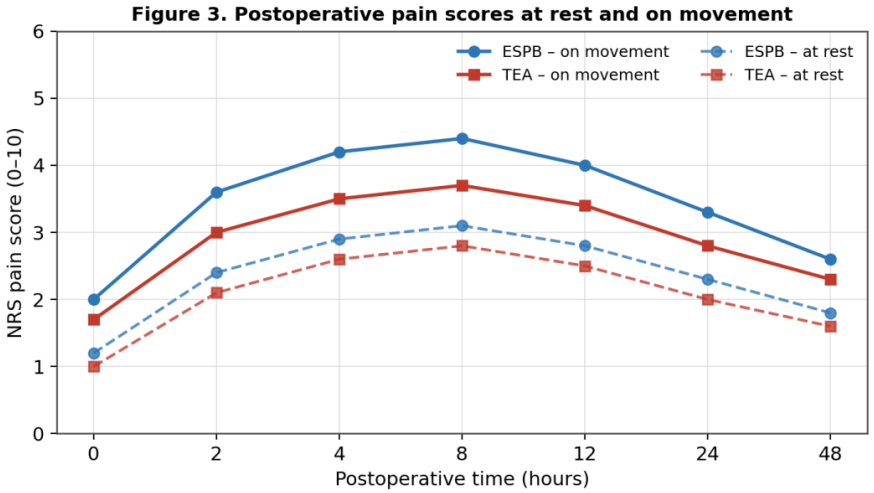

Figure 3. NRS pain scores at rest (dashed) and on movement (solid) over 48 h. Between-group differences were small and statistically significant for movement scores at 4 h.

Table 3. NRS pain scores at rest and on movement (mean ± SD).

Time (h)	Rest – E	Rest – T	p	Movement E / T (p)
0	1.2 ± 0.8	1.0 ± 0.7	0.27	2.0 / 1.7 (0.19)
2	2.4 ± 1.1	2.1 ± 1.0	0.24	3.6 / 3.0 (0.05)
4	2.9 ± 1.2	2.6 ± 1.1	0.28	4.2 / 3.5 (0.04)
8	3.1 ± 1.3	2.8 ± 1.2	0.32	4.4 / 3.7 (0.05)
12	2.8 ± 1.1	2.5 ± 1.0	0.24	4.0 / 3.4 (0.06)
24	2.3 ± 1.0	2.0 ± 0.9	0.19	3.3 / 2.8 (0.08)
48	1.8 ± 0.8	1.6 ± 0.8	0.30	2.6 / 2.3 (0.21)

Opioid consumption and recovery outcomes

Cumulative 24-h opioid consumption was lower in the TEA group (16.2 ± 6.4 mg) than in the ESPB group (19.6 ± 7.1 mg morphine equivalents, p = 0.039), and the time to first rescue analgesia was longer with TEA (7.9 ± 2.4 vs 6.8 ± 2.1 h, p = 0.046). Conversely, ESPB was faster to perform (8.2 ± 2.1 vs 12.6 ± 3.4 min, p < 0.001) with no block failures, compared with three inadequate epidurals (8.6%) in Group T. Recovery-related outcomes favoured ESPB: PONV (11.4% vs 28.6%, p = 0.07) and urinary retention (2.9% vs 22.9%, p = 0.027) were less frequent, and patients ambulated earlier (18.2 ± 4.1 vs 24.6 ± 5.3 h, p < 0.001). Time to first flatus, patient satisfaction and length of stay did not differ significantly (Table 4).

Table 4. Secondary analgesic and recovery outcomes.

Outcome	Group E (ESPB)	Group T (TEA)	p value
24-h opioid consumption (mg ME)	19.6 ± 7.1	16.2 ± 6.4	0.039
Time to first rescue (h)	6.8 ± 2.1	7.9 ± 2.4	0.046
Block performance time (min)	8.2 ± 2.1	12.6 ± 3.4	<0.001
Block failure / inadequate, n (%)	0 (0)	3 (8.6)	0.24
PONV, n (%)	4 (11.4)	10 (28.6)	0.07
Urinary retention, n (%)	1 (2.9)	8 (22.9)	0.027
Time to ambulation (h)	18.2 ± 4.1	24.6 ± 5.3	<0.001
Time to first flatus (h)	28.4 ± 6.2	26.1 ± 5.8	0.12
Patient satisfaction (0–10)	8.4 ± 1.1	8.1 ± 1.3	0.29
Length of hospital stay (days)	5.1 ± 1.2	5.6 ± 1.4	0.11

DISCUSSION

In this randomized comparison in major abdominal surgery, ESPB and TEA both delivered effective analgesia, but the two techniques were not equivalent across all analgesic endpoints. Resting pain scores were indistinguishable; however, TEA consistently produced lower dynamic pain scores—reaching statistical significance at 4 h—together

with significantly lower 24-h opioid consumption and a longer time to first rescue analgesia. These findings indicate that a well-functioning epidural still provides the more complete dynamic and opioid-sparing analgesia, consistent with its more comprehensive neural blockade [4,5]. ESPB should therefore be regarded as providing analgesia that approaches, rather than matches, that of TEA [15,16,17].

The principal advantage of ESPB was haemodynamic. TEA more than doubled the incidence of intraoperative hypotension and vasopressor requirement, produced a sustained fall in MAP during the first operative hour, and required larger cumulative vasopressor doses. This is the expected consequence of the segmental sympathetic blockade intrinsic to neuraxial local anaesthetic, which reduces venous return and systemic vascular resistance [4,6,7]. Hypotension after epidural analgesia is reported in roughly a third of patients and is a recognized limitation within ERAS pathways, where haemodynamic instability and the fluid loading used to counter it are themselves associated with worse outcomes [5,8,24]. By contrast, the ESPB is performed remote from the neuraxis; although recent work shows variable paravertebral and epidural spread and some effect on sympathetic fibres, its haemodynamic footprint is consistently smaller [10,11,12]. Our results parallel comparative studies in cardiac and thoracic surgery, in which ESPB matched or approached the analgesia of TEA with greater cardiovascular stability [18,19,20].

The mechanism underlying ESPB analgesia remains incompletely resolved. Cadaveric and radiological studies show cranio-caudal spread within the fascial plane with inconsistent penetration to the paravertebral and epidural compartments, and the block is increasingly understood as a composite of local neural blockade of the dorsal and ventral rami, variable paravertebral diffusion, and a systemic contribution from absorbed local anaesthetic [10,11,12]. This multifactorial and somewhat less predictable action plausibly explains the higher rescue-opioid requirement and higher dynamic pain scores we observed relative to a functioning epidural [16,22]. Notably, the greater opioid use with ESPB was not accompanied by more opioid-related nausea—PONV was in fact numerically lower—probably reflecting reduced neuraxial opioid exposure and the absence of sympathetic block [15,17].

Beyond haemodynamics, the safety and workflow profile of ESPB was favourable. The block was quicker to perform, had no failures, and was associated with markedly less urinary retention and earlier ambulation—outcomes central to enhanced recovery [2,5]. The near-absence of serious risk is important: TEA carries rare but devastating complications including epidural haematoma and abscess, is precluded by coagulopathy and anticoagulation, and has a well-documented clinical failure rate, exemplified by the three inadequate epidurals in our cohort [4,6,7,13]. These pragmatic advantages must, however, be weighed against the superior dynamic analgesia of a successful epidural.

Several limitations temper these conclusions. First, the interventions could not be blinded to the operator, although assessors and patients were. Second, this was a single-centre study of modest size; the sample was powered primarily for the haemodynamic and analgesic co-primary outcomes using effect sizes borrowed from adjacent populations, so it may be underpowered for less frequent secondary endpoints, and a dedicated prospective pilot would have allowed more precise a priori estimates. Third, the heterogeneous mix of upper and lower abdominal procedures, though reflecting real practice and balanced between groups (Table 1), may obscure procedure-specific differences, and our use of a single standardized T8 injection—chosen for reproducibility and broad dermatomal coverage—may be suboptimal for purely lower-abdominal or pelvic surgery, where a lower injection level might improve efficacy [11,16]. Fourth, we did not measure plasma local-anaesthetic concentrations, stress-response biomarkers or persistent post-surgical pain. Larger multicentre trials stratified by surgical site, incorporating continuous-catheter protocols and pharmacokinetic data, are needed to define where ESPB can substitute for TEA [16,21,22].

Taken together with the wider literature, our data support a nuanced position: TEA remains the benchmark for dynamic, opioid-sparing analgesia after major abdominal surgery, while ESPB offers a favourable balance of effective analgesia and superior haemodynamic stability with fewer side effects. ESPB is thus a valuable alternative—particularly for patients in whom haemodynamic instability is a concern or neuraxial block is contraindicated—rather than a wholesale replacement for a functioning epidural [5,8,13].

CONCLUSION

In major abdominal surgery, ultrasound-guided ESPB provided analgesia approaching that of TEA while conferring significantly greater haemodynamic stability, less vasopressor use, fewer episodes of urinary retention and PONV, and earlier ambulation, at the cost of modestly higher opioid consumption and slightly higher dynamic pain scores. Given its technical simplicity, high success rate and favourable safety profile, ESPB is an

effective alternative to TEA within multimodal, enhanced-recovery regimens, especially when haemodynamic stability is a priority or neuraxial block is contraindicated. Larger, procedure-specific multicentre trials are warranted to confirm these findings.

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