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Research Article

Evaluation of Ultrasound-Guided Erector Spinae Plane Block for Intraoperative Hemodynamic Stability and Postoperative Pain Relief in Laparoscopic Cholecystectomy: A Randomized Controlled Trial

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ABSTRACT

Background: Laparoscopic cholecystectomy, although minimally invasive, frequently provokes sympathetic surges during pneumoperitoneum and significant early visceral pain, necessitating opioids that delay recovery. The ultrasound-guided erector spinae plane block (ESPB) has emerged as a simple interfascial technique with paravertebral spread that might blunt these responses.

Objective: To evaluate whether pre-incision bilateral ESPB enhances intra-operative haemodynamic stability and reduces opioid consumption and early pain after laparoscopic cholecystectomy.

Methods: Sixty adults (ASA I–II) scheduled for elective laparoscopic cholecystectomy were randomly assigned to receive either bilateral ESPB at T7 with 20 mL of 0.25% bupivacaine per side combined with standard general anesthesia (ESPB group, n = 30) or general anesthesia alone (Control, n = 30). Hemodynamic parameters—heart rate (HR), systolic and diastolic blood pressure (SBP, DBP), and mean arterial pressure (MAP)—were recorded. Fentanyl boluses were administered if there was a 20% increase from baseline in heart rate or mean blood pressure. Total intraoperative fentanyl consumption was documented. If heart rate or mean blood pressure remained more than 20% above baseline, a 20 mg bolus of propofol was given. In resistant cases, where fentanyl and propofol were ineffective, 0.5 mg IV boluses of metoprolol were administered, and the total amount given was recorded. Postoperatively, patients were monitored for pain using a Numerical Rating Scale (NRS) at 30 minutes, and at 1, 2, 4, 8, and 12 hours. If the NRS score exceeded 4, 1 mg/kg IV tramadol was administered. Adverse events were noted.

Results: The groups were similar in age, sex, ASA class, and surgical duration. ESPB resulted in lower HR from 10 to 90 minutes after pneumoperitoneum ($p < 0.05$). No significant differences were observed in mean SBP and DBP at any time point ($p > 0.05$) between the groups. The mean MAP difference was not statistically significant, except at 5 and 60 minutes ($p < 0.05$). Cumulative intraoperative fentanyl (116.7 ± 24.0 µg vs. 131.7 ± 24.5 µg; $p = 0.02$) and propofol supplementation (17% vs. 50%; $p = 0.013$) were reduced, along with metoprolol use (10% vs. 40%; $p < 0.01$). Postoperative tramadol requirement decreased by 42% ($p < 0.01$), and NRS scores were significantly lower at 0.5, 2, 4, 8, and 12 hours ($p < 0.05$). Shoulder-tip pain and nausea were lower but not statistically different.

Conclusions: Pre-operative bilateral ESPB provides significant hemodynamic stability. This stability is demonstrated by a notable decrease in intraoperative fentanyl use, anesthetic needs, and vasodepressor requirements compared to the control group, along with superior early analgesia without additional complications. Incorporating ESPB into enhanced recovery pathways for laparoscopic cholecystectomy may hasten ambulation and discharge.

Keywords: Erector Spinae Plane Block; Laparoscopic Cholecystectomy; Haemodynamic Stability; Opioid-Sparing; Ultrasound-Guided Regional Anaesthesia.

INTRODUCTION

Laparoscopic cholecystectomy (LC) has displaced open surgery as the gold standard for symptomatic cholelithiasis, yet the physiological perturbations it induces remain substantial. Carbon-dioxide pneumoperitoneum and reverse-Trendelenburg positioning elevate systemic vascular resistance, reduce venous return, and trigger catecholamine, renin, and vasopressin release [1–3]. Peaks in heart rate

(HR) and mean arterial pressure (MAP) commonly mandate intra-operative opioid or β-blocker supplementation. Post-operatively, visceral irritation and residual intraperitoneal gas generate moderate-to-severe pain, often necessitating opioids and prolonging recovery [4]. Enhanced-Recovery-After-Surgery (ERAS) protocols emphasize multimodal opioid-sparing strategies. Fascial-plane blocks, including the transversus abdominis plane and oblique subcostal TAP blocks, attenuate somatic pain but provide limited visceral coverage. The erector spinae plane block (ESPB), first described by Forero et al. in 2016 [5], deposits local anaesthetic deep to the erector spinae muscle, diffusing cranio-caudally and anteriorly through the costotransverse foramen to the paravertebral and epidural spaces. Case reports and small series suggest ESPB yields multi-dermatomal sensory and sympathetic blockade, improves analgesia after abdominal surgery, and may blunt haemodynamic responses [6–8, 16]. Beyond catecholaminergic surges, neuro-endocrine studies demonstrate pronounced elevations in vasopressin and other stress hormones during laparoscopy, especially when steep head-up or head-down tilts are combined with pneumoperitoneum [9–11]. These hormonal changes further compromise venous return and myocardial performance, explaining the frequent need for intra-operative cardiostability agents. Concurrently, basic science work on visceral nociception has clarified that gall-bladder and peritoneal afferents converge on thoracic sympathetic pathways, amplifying pain perception via sensitisation of the central nervous system [12–15]. A comprehensive block, such as ESPB, capable of reaching both somatic and sympathetic fibers, is therefore pathophysiologically appealing. The quest for an ideal regional strategy that simultaneously tempers haemodynamic swings and minimizes postoperative pain continues. We tested the hypothesis that "Pre-induction bilateral ultrasound-guided ESPB attenuated intraoperative HR and MAP surges, reduced opioid and anaesthetic requirements, and decreased early postoperative pain and tramadol consumption compared with standard care."

METHODS

Study Design and Participants

This single-center, parallel-group, randomized controlled trial was conducted at Jagjivan Ram Railway Hospital in Mumbai. Written informed consent was obtained from all participants. Inclusion criteria were adults aged 18–65 years, ASA physical status I–II, scheduled for elective LC. Exclusion criteria comprised patient refusal, allergy to amide local anaesthetics, coagulopathy, infection at the needle entry site, conversion to open surgery, or significant cardiopulmonary disease.

Randomization and Masking

Sixty subjects were randomly assigned using a computer-generated sequence concealed in opaque envelopes, which were opened immediately before the start of each block. Owing to the nature of the intervention, the procedural anaesthesiologist was unblinded; surgeons and data collectors were blinded to group allocation.

Interventions

ESPB group (Group A). In the sitting position, a high-frequency linear transducer (13–6 MHz) was placed 3 cm lateral to the T7 spinous process. After skin infiltration with 2% lignocaine, a 22-G, 80-mm needle was advanced in-plane to contact the T7 transverse process. Following hydro-dissection, 20 mL 0.25 % bupivacaine was injected deep to the erector spinae muscle; the procedure was repeated contralaterally.

Control Group (Group B). No regional block was performed.

All patients then received a standardized general anesthesia: Inj. Glycopyrrolate 0.004 mg/kg, Inj. midazolam 0.02 $mg \cdot kg^{-1}$, fentanyl 2 $\mu g \cdot kg^{-1}$, propofol 2 $mg \cdot kg^{-1}$, succinylcholine 1.5 $mg \cdot kg^{-1}$ for intubation, and sevoflurane in 60% N_2O/O_2 with intermittent vecuronium. Pneumoperitoneum was maintained at 12–14 mmHg.

Intra-Operative Management

Fentanyl 50 μg boluses treated increases of ≥20% above baseline HR or MAP; persistent tachycardia or hypertension prompted the administration of propofol 20 mg and, if needed, metoprolol 0.5 mg IV. Hypotension (MAP <65 mmHg) was managed with Inj. mephentermine 3 mg. Crystalloid administration and estimated blood loss were recorded.

Outcomes

Primary outcomes:

- HR, SPB, DPB, and MAP were measured at baseline, after the block (Group A only), during intubation, at the start of

pneumoperitoneum, and then at 5, 10, 15, 30, 45, 60, 75, and 90 minutes later, as well as at extubation.
- Cumulative intraoperative doses of fentanyl, propofol, and metoprolol;
- Postoperative NRS pain scores at 0.5, 1, 2, 4, 8, and 12 hours.

Secondary outcomes
- Cumulative tramadol requirement (1 $mg \cdot kg^{-1}$ IV if NRS > 4);
- Incidence of shoulder-tip pain, postoperative nausea and vomiting (PONV), hypotension, bradycardia, pneumothorax, or local anesthetic systemic toxicity (LAST).

Statistical Analysis
A sample of 30 per group provided 80% power ($\alpha = 0.05$) to detect a 10-bpm difference in mean HR (SD ± 15). Data were analyzed with SPSS v21. Continuous variables are mean ± SD and compared with unpaired t-test or Mann–Whitney U as appropriate; categorical data were analyzed with χ^2 or Fisher's exact test. $P < 0.05$ was considered significant.

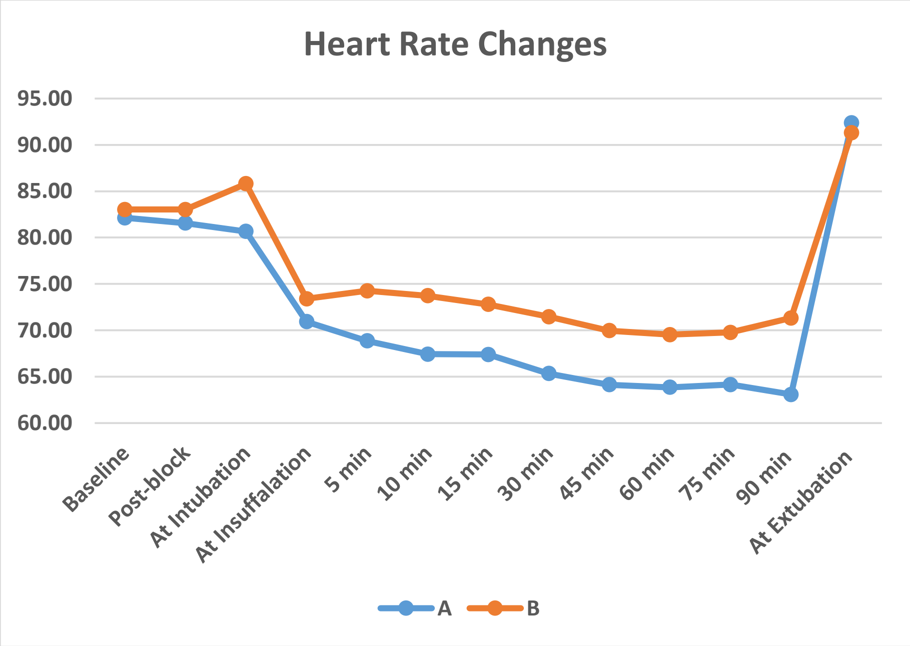
RESULTS

Table/Figure 1. Baseline Characteristics

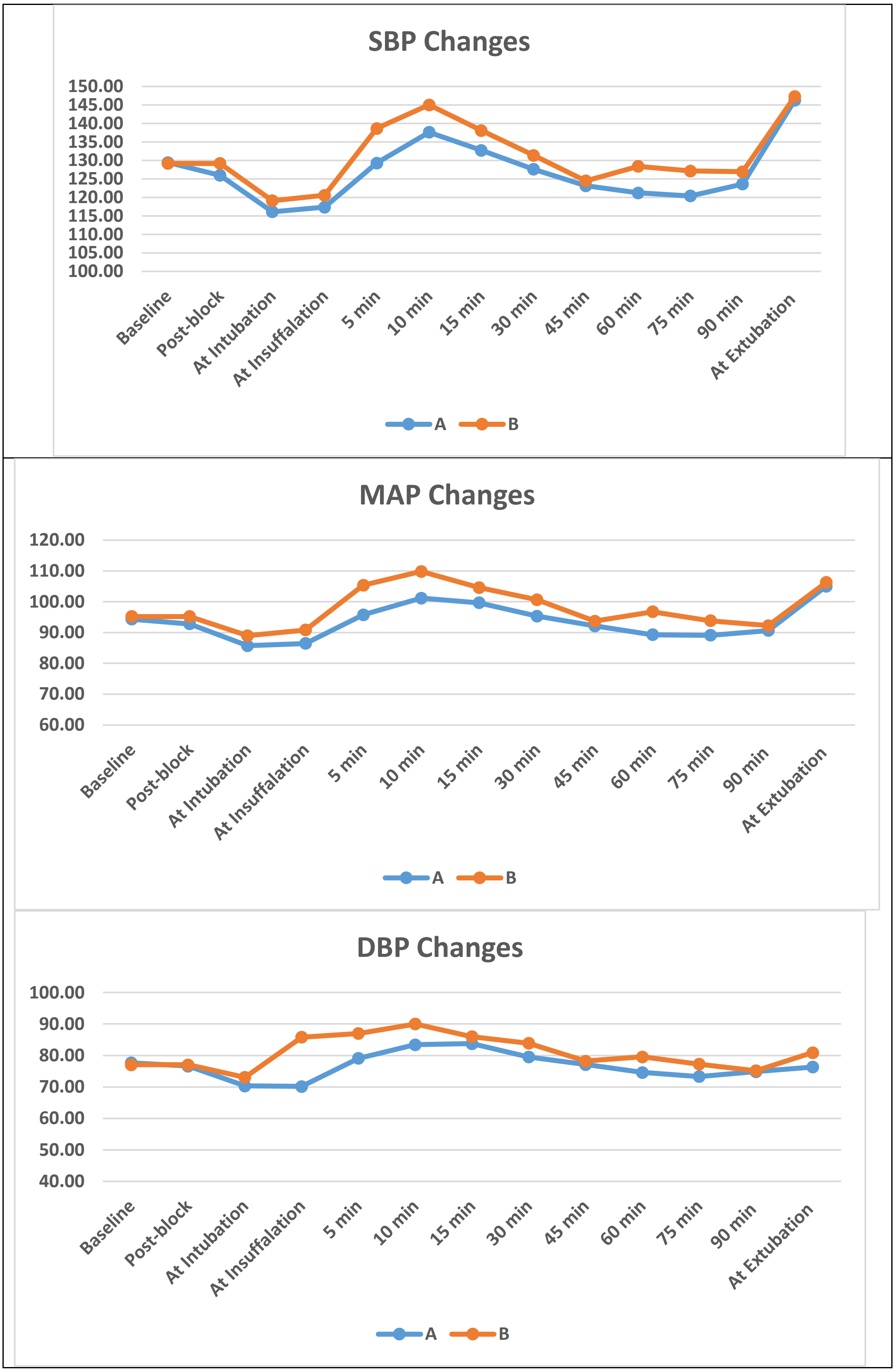
	ESPB (n = 30)	Control (n = 30)	*P*
Age (y)	48.1 ± 15.5	51.2 ± 11.4	0.26
Female: Male	21: 9	17: 13	0.42
Weight (kg)	60.5 ± 6.1	64.3 ± 9.4	0.07
ASA I / II	10 / 20	7 / 23	0.57
Surgery duration (min)	109 ± 13	115 ± 14	0.12

Baseline demographic and operative variables were comparable across groups. The mean age was comparable (48.1 ± 15.5 years in the ESPB cohort vs 51.2 ± 11.4 years in controls; p = 0.26), with no significant difference in sex distribution (female-to-male ratio 21:9 vs 17:13; p = 0.42). Average body weight (60.5 ± 6.1 kg vs 64.3 ± 9.4 kg; p = 0.07) and ASA physical status proportions (I/II = 10/20 vs 7/23; p = 0.57) were also comparable. Surgical duration did not significantly differ between groups (109 ± 13 minutes vs 115 ± 14 minutes; p = 0.12) (Table/Figure 1).
The comparison of mean heart rates between the two groups was statistically significant at 10, 30, 45, 60, 75, and 90 minutes (Table/Figure 2).

Table/Figure 2-Comparison of Mean Heart Rate Changes between Study Groups



Table/Figure 3. Comparison of Blood Pressure Changes between Study Groups



The mean systolic blood pressure was statistically significant compared between the two groups at 60 and 90 minutes. The mean diastolic blood pressure was not statistically significant when compared between the two groups at any time point. The mean blood pressure was statistically significant compared between the two groups at 5 and 60 minutes (Table/Figure 3).

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Table/Figure 4. Intra-Operative Pharmacologic Support.

	ESPB	Control	P
Fentanyl (µg)	116.7 ± 24.0	131.7 ± 24.5	0.02
Propofol bolus given	5 (17 %)	15 (50 %)	0.013
Metoprolol required	3 (10 %)	12 (40 %)	<0.01
Mephentermine required	0	1 (3 %)	1.00
Blood loss (mL)	35 ± 18	41 ± 14	0.07

The ESPB cohort required markedly less intraoperative pharmacologic support than Controls. Mean fentanyl consumption fell by 11 % (116.7 ± 24.0 µg vs 131.7 ± 24.5 µg; p = 0.02), and the proportion needing rescue propofol halved (17 % vs 50 %; p = 0.013). β-blocker supplementation with metoprolol was also substantially lower (10% vs 40%; p < 0.01). Mephentermine use was negligible in both groups (0 vs 3 %; p = 1.00), and estimated blood loss remained comparable (35 ± 18 mL vs 41 ± 14 mL; p = 0.07) (Table/Figure 4).

Table/Figure 5. Pain Scores

	0.5 h	1h	2 h	4 h	8 h	12 h	Tramadol (mg)
ESPB	4.2 ± 1.5	3.13±1.20	2.7 ± 1.1	2.1 ± 1.0	1.6 ± 0.7	1.1 ± 0.9	39 ± 46
Control	5.3 ± 1.8	3.70±1.37	3.6 ± 1.5	3.0 ± 1.3	2.5 ± 0.9	1.9 ± 1.1	67 ± 53
P	0.01	0.09	<0.01	<0.01	<0.01	<0.01	<0.01

NRS scores were lower in the ESPB group at all time points except at one hour; differences were significant at 0.5, 2, 4, 8, and 12 hours (Table/Figure 5). Cumulative tramadol over 12 hours was reduced by 42% (39 ± 46 mg vs 67 ± 53 mg; p < 0.01.

Adverse Events

Shoulder-tip pain occurred in 7 patients vs. 6 (NS); PONV in 2 patients vs. 7 (NS). No pneumothorax, LAST, severe hypotension, or bradycardia occurred.

DISCUSSION

Our findings contribute to an expanding body of research highlighting ESPB as a flexible component of ERAS protocols for LC. The hemodynamic stabilization observed aligns with previous endocrine studies, which have shown increases in vasopressin and catecholamines during pneumoperitoneum [9–11]. By encompassing the sympathetic chain within its spread, ESPB likely influences these neuroendocrine responses, explaining the 66% decrease in rescue propofol use and the 75% reduction in β-blocker utilization observed in our cohort. Analgesic results are comparable to those of recent studies. Petsas et al. first reported effective ESPB-mediated pain relief after LC in a single case report [16], and later randomized trials by Altiparmak et al. [17] and Tulgar et al. [18] confirmed significant opioid-sparing effects compared to TAP or sham blocks. Ibrahim's 2020 trial further showed a 30% decrease in 24-hour morphine equivalents, similar to our 42% reduction in tramadol [19]. Kwon et al. [20] found that ultrasound-guided Erector Spinae Plane Block (ESPB) combined with Rectus Sheath Block (RSB) decreased the need for intraoperative remifentanil and reduced total analgesic use within the first 24 hours for patients undergoing laparoscopic cholecystectomy (LC) compared to those receiving RSB alone. This suggests that ESPB may have a beneficial visceral analgesic effect. Paediatric data from Aksu and Gurkan [21] suggest ESPB's benefits extend across age groups, supporting its safety profile. Anatomically, high-resolution MRI and cadaveric dye studies show thoracic ESPB spread to both dorsal and ventral rami, paravertebral space, and epidural recesses [22]. This three-compartment spread explains the simultaneous attenuation of nociceptive and sympathetic pathways we observed. However, block-related complications, such as pneumothorax, motor weakness, and local anesthetic toxicity, are rarely reported; none occurred in our series, which is consistent with published safety data [17–19, 22]. Limitations include the single-center design, moderate sample size, and lack of sensory-level mapping, which could have provided a more accurate clarification of the precise dermatomal spread. Future multi-center trials with objective autonomic measures and longer follow-up may better define ESPB's impact on recovery metrics such as hospital length of stay and patient-reported quality of recovery. In conclusion, bilateral ESPB before LC offers a mechanistically plausible and clinically effective approach to addressing the challenges of hemodynamic instability and visceral pain. Broad use could improve ERAS adherence, reduce opioid reliance, and support quicker discharge in minimally invasive biliary surgery.

Conclusions

Ultrasound-guided bilateral ESPB administered before laparoscopic cholecystectomy significantly enhances intraoperative hemodynamic stability and provides better early postoperative pain relief while lowering opioid and anesthetic adjunct use, without increasing adverse events. Adding ESPB to routine LC protocols may improve perioperative quality and support opioid-sparing recovery pathways.

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