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Research Article

Effects of Erector Spinae Plane Block on Hemodynamic Stability, Postoperative Pain, and Serum Interleukin-6 in Elective Laparoscopic Cholecystectomy: A Randomized Controlled Trial

Fikri Samodro Putro*, Andi Salahudin, Alamsyah Ambo Ala, Syafruddin Gaus, Muh. Takdir Musba, Charles Wijaya Tan

Department of Anesthesiology and Intensive Care, Faculty of Medicine, Hasanuddin University, Makassar, Indonesia.

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ABSTRACT

Background: Laparoscopic cholecystectomy (LC) triggers hemodynamic instability and systemic inflammation through sympatho-adrenal activation. The erector spinae plane block (ESPB) is a promising analgesic adjunct, yet its effect on surgical inflammatory response remains inadequately studied. This trial compared bilateral ESPB plus general anesthesia versus general anesthesia only on hemodynamics, postoperative pain, and serum interleukin-6 (IL-6) in elective LC.
Methods: Seventy-two adults undergoing elective LC were randomized equally to a control group (general anesthesia only, n = 36) or an ESPB group (bilateral ultrasound-guided ESPB with 20 mL of 0.25% bupivacaine per side before induction, n = 36). Mean arterial pressure (MAP) and heart rate (HR) were recorded at baseline and every 15 minutes intraoperatively through extubation. Pain was scored by the Numeric Rating Scale (NRS) at 2, 6, and 24 hours postoperatively. Serum IL-6 was measured preoperatively, post-extubation, and at 6 and 24 hours.
Results: Baseline characteristics were comparable ($p > 0.05$). The ESPB Group had significantly lower MAP and HR at all intraoperative time points and extubation ($p < 0.05$). NRS scores were significantly lower at 2, 6, and 24 hours ($p < 0.05$). IL-6 was significantly attenuated at all postoperative time points, with the greatest difference at 6 hours (median 63.28 vs. 70.65 pg/mL; $p = 0.001$). No adverse events were recorded.
Conclusion: Bilateral ESPB combined with general anesthesia improves intraoperative hemodynamic stability, sustains analgesia for 24 hours, and attenuates systemic inflammation versus general anesthesia only in elective LC, supporting its incorporation into multimodal anesthetic protocols.

Introduction

Laparoscopic cholecystectomy (LC) is the established gold standard for the surgical management of gallbladder disease, offering well-documented advantages over open surgery, including reduced surgical site infection, shorter hospitalization, and earlier recovery [1]. Despite its minimally invasive nature, LC is not without physiological consequences. Carbon dioxide pneumoperitoneum raises intra-abdominal pressure to 12–15 mmHg, compressing the inferior vena cava, reducing venous return, and precipitating hemodynamic instability. Concurrent CO_2

The authors declare no conflicts of interest.
*Corresponding author.
E-mail address: fikrisamudro@gmail.com
DOI:

absorption and surgical stimulation activate the sympatho-adrenal axis, producing catecholamine-mediated tachycardia, hypertension, and a systemic inflammatory response characterized by markedly elevated serum Interleukin-6 (IL-6), a validated early biomarker of surgical stress whose magnitude correlates with operative trauma and postoperative morbidity [2-3].

Although general anesthesia is required to manage the ventilatory demands of pneumoperitoneum, it incompletely suppresses these neuroendocrine and inflammatory responses [4]. The Erector Spinae Plane Block (ESPB), first described by Forero et al. in 2016, has emerged as a promising analgesic adjunct in which local anesthetic is deposited deep to the erector spinae muscle, spreading to the dorsal and ventral rami of thoracolumbar spinal nerves, providing multilevel somatic and potential visceral analgesia [5]. Preliminary evidence suggests that bilateral thoracic ESPB may attenuate intraoperative hemodynamic perturbation and reduce postoperative opioid consumption in laparoscopic abdominal surgery [6-7]. However, its effect on the systemic inflammatory response, particularly serum IL-6 in patients undergoing LC, has not been adequately investigated.

Therefore, this study aimed to compare the effects of bilateral ESPB combined with general anesthesia versus general anesthesia alone on intraoperative hemodynamic profiles (SBP, DBP, MAP, and HR), postoperative pain intensity (Numeric Rating Scale), and serum IL-6 concentrations at four hours after surgery in patients undergoing elective laparoscopic cholecystectomy.

Methods

Study Design and Setting

This study was a prospective, randomized, double-arm experimental clinical trial. The research was conducted 1 year from January to March 2026 at RSUP Wahidin Sudirohusodo. This study compares the effects of the General anesthesia with Erector Spinae Plane Block and General anesthesia only. The evaluate outcome were gender, age, blood pressure, hemodynamics, postoperative pain, and serum interleukin-6 (IL-6) in elective LC.

Participant Selection

The study population comprised adult patients scheduled for elective laparoscopic cholecystectomy. Patients were eligible for inclusion if they met all of the following criteria: (1) age >18 years; (2) American Society of Anesthesiologists (ASA) physical status classification I or II; (3) willingness to participate with provision of signed informed consent; and (4) approval from the primary attending physician. Patients were excluded if they: (1) declined to participate, or (2) had comorbidities or anatomical abnormalities that could independently affect hemodynamic stability. Any participant who met an exclusion criterion after enrollment was withdrawn from the analysis.

Randomization and Intervention

Eligible participants were randomly allocated into two equal groups:

1. *ESPB Grou*p (*n* = 36): Received bilateral ultrasound-guided erector spinae plane block prior to anesthetic induction.
2. *Control Grou*p (*n* = 36): Received standard general anesthesia (GA) without ESPB.

All patients underwent the same premedication and induction procedure. The night before their operation, they were given ranitidine 150 mg orally. Half an hour prior to the procedure, four medications were delivered intravenously: ranitidine 50 mg, ondansetron 4 mg, dexketoprofen 25 mg, and paracetamol 1000 mg.

In the ESPB Group, bilateral nerve blocks were carried out at the transverse process level under continuous ultrasound visualization, with a 21-gauge hypodermic needle used to perform the procedure. After skin preparation with 70% alcohol followed by 10% povidone-iodine, the erector spinae fascial plane was identified sonographically. A total of 40 mL of 0.25% bupivacaine (20 mL per side) was injected into the plane, and correct injectate spread was confirmed by ultrasonography.

General anesthesia was induced identically in both groups using IV fentanyl 2 μg/kg and IV propofol 1.0–2.5 mg/kg. Tracheal intubation was facilitated with IV rocuronium 1 mg/kg. Anesthesia was sustained using isoflurane at a concentration of 1.0–1.5 vol%, delivered through an oxygen and air mixture at 2 L/min each, along with a steady intravenous fentanyl infusion running at 0.5 μg/kg/h.

Prior to the start of surgery, baseline hemodynamic measurements were documented, encompassing systolic blood pressure, diastolic blood pressure, mean arterial pressure, and heart rate. Intraoperatively, these parameters were monitored continuously and recorded at 15-minute intervals. A predefined rescue protocol was applied to both groups. If MAP or HR increased by more than 25% from baseline, a rescue bolus of IV fentanyl 1 μg/kg was administered, and isoflurane was up titrated to 1.5 vol%. If MAP decreased by more than 25% from baseline, isoflurane was reduced to 1.0 vol%, and a 500 mL crystalloid bolus was infused. Persistent hypotension was treated with IV ephedrine 5–10 mg.

Outcome Measures

Both primary and secondary outcomes included hemodynamic measurements, a systemic inflammatory indicator, and pain levels following surgery. Hemodynamic stability was evaluated by documenting systolic blood pressure, diastolic blood pressure, mean arterial pressure, and heart rate at baseline before the operation and at every 15-minute interval throughout the procedure. The systemic inflammatory response was measured through serum IL-6 levels, analyzed via an enzyme-linked immunosorbent assay kit. Venous blood samples were drawn at two separate time points: before surgery and four hours after its completion. IL-6 levels were categorized as either normal, defined as 15 pg/mL or below, or elevated, defined as above 15 pg/mL. Pain intensity after surgery was evaluated six hours post-procedure using the Numeric Rating Scale, where zero indicates no pain and ten represents the worst pain conceivable, and assessments were conducted by trained staff who were unaware of each patient's group assignment.

Statistical Analysis

Data were analyzed using SPSS for Windows, version 26.0. Demographic and baseline characteristics were summarized as frequencies and percentages for categorical variables, and as mean ± standard deviation (SD) or median (interquartile range) for continuous variables, according to the distribution of the data.

Statistical analysis included the normality test, parametric and non parametric test. p-value <0.05 was considered statistically significant, indicating an association between the studied factors and calcium score values in diabetic patients. The results were presented in narrative form and supported by tables and figures.

Ethical Considerations

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical clearance was granted by the Health Research Ethics Committee of Universitas Hasanuddin, Makassar, Indonesia (Ethical Clearance Number: 1054/UN4/6/4/5/31/PP36/2025). Written informed consent was obtained from all participants prior to enrollment.

Results

Baseline Characteristics

A total of 72 patients undergoing elective laparoscopic cholecystectomy were enrolled and allocated equally to the control group (*n* = 36) and the ESPB group (*n* = 36). Baseline demographic and clinical characteristics are presented in (Table 1).

The mean age was 43.05 ± 10.34 years in the control group and 40.67 ± 13.79 years in the ESPB group, with no statistically significant difference between groups (Mann-Whitney U test, p = 0.832). Sex distribution did not differ significantly between groups (p = 0.173): female patients predominated in both the control group (83.3%) and the ESPB group (66.7%). Median BMI was 22.60 kg/m² (range 19.70–28.30) and 24.21 kg/m² (range 18.20–29.10) in the control and ESPB groups, respectively.

The distribution of comorbidities, including diabetes mellitus, hypertension, and coronary artery disease, was comparable between groups (p = 0.277). The absence of significant between-group differences across all baseline variables confirms successful randomization and ensures that any outcome differences can be attributed to the intervention rather than to pre-existing participant characteristics.

Table 1- Baseline Demographic and Clinical Characteristics by Group

Characteristic	Control Group (*n* = 36)	ESPB Group (*n* = 36)	P value
Age (years), mean ± SD	43.05 ± 10.34[a]	40.67 ± 13.79[a]	0.832
Sex, *n* (%)			0.173
Male	6 (16.7)	12 (33.3)	
Female	30 (83.3)	24 (66.7)	
BMI (kg/m²), median (range)	22.60 (19.70–28.30)[b]	24.21 (18.20–29.10)[b]	—
Comorbidities, *n* (%)			0.277
Diabetes mellitus	3 (8.3)	8 (22.2)	
Hypertension	2 (5.6)	4 (11.1)	
Coronary artery disease	1 (2.8)	1 (2.8)	

Continuous data are expressed as mean ± SD or median (range) and compared using the Mann-Whitney U test. [a] Categorical data are expressed as numbers (percentages) and compared using the Chi-square test. [b] BMI, body mass index; SD, standard deviation. p < 0.05 denotes statistical significance.

Hemodynamic Stability

Mean Arterial Pressure

(Table 2) shows comparative of preoperative MAP between the control and intervention groups (90.5 (84.0–97.0) vs. 90.5 (84.0–96.0) mmHg, p=0.795). Following intubation, the intervention group maintained significantly lower MAP throughout the procedure (p<0.05). Median MAP was lower in the intervention group at 15 minutes post-intubation (96.0 vs. 98.5 mmHg, p=0.016), 30 minutes intraoperatively (98.0 vs. 101.0 mmHg, p=0.004), and 45 minutes intraoperatively (96.5 vs. 98.5 mmHg, p=0.030). Extubation stress caused a MAP surge in both groups, but the increase was significantly attenuated in the intervention group (102.0 (95.0–107.0) vs. 103.5 (100.0–108.0) mmHg, p=0.002).

Heart Rate

Preoperative heart rate was comparable between the control and intervention groups (Table 3). Following intubation, the intervention group maintained significantly lower and more stable heart rates throughout the procedure (p<0.05). Median heart rate was lower in the intervention group at 15 minutes post-intubation (85.5 vs. 81 bpm, p=0.028), 30 minutes intraoperatively (89 vs. 84 bpm, p=0.004), and 45 minutes intraoperatively (85 vs. 82 bpm, p=0.001). Extubation stress caused a heart rate surge in both groups, but the increase was significantly attenuated in the intervention group (95.5 (90–103) vs. 90.5 (81–100) bpm, p=0.001).

Postoperative Pain Intensity

As shown in (Table 4), the intervention group demonstrated consistently and significantly lower NRS pain scores across all postoperative time points (p < 0.05). At 2 hours post-surgery, the control group reported moderate-to-severe pain [median NRS 6 (4–8)], whereas the intervention group reported mild-to-moderate pain (4.5 (2–8); p = 0.003). This superior analgesic effect persisted at 6 hours (3 (2–6) vs. 5 (3–6); p = 0.012), reflecting reduced early opioid requirements, and remained statistically significant even at 24 hours (2 (1–5) vs. 3 (2–5); p = 0.009).

IL-6 Concentrations

Baseline IL-6 levels (Table 5) were comparable between the control and ESPB groups (10.07 (8.03–12.18) vs. 9.81 (8.05–12.00) pg/mL, p = 0.478). While surgical trauma and pneumoperitoneum induced a postoperative inflammatory response across both cohorts, the block significantly mitigated this surge.Immediately post-extubation, median IL-6 was significantly lower in the ESPB group than in controls (53.45 (46.27–88.89) vs. 58.26 (52.18–64.36) pg/mL, p = 0.004). Levels peaked in both groups at 6 hours postoperatively, where the ESPB group demonstrated a significantly blunted maximum response (63.28 (50.57–75.94) vs. 70.65 (60.94–80.36) pg/mL, p = 0.001$), representing the widest between-group variance. By 24 hours, concentrations had declined but remained lower in the ESPB cohort (33.69 (24.49–43.56) vs. 36.93 (28.05–48.05) pg/mL, p = 0.013).

Table 2- Intraoperative Mean Arterial Pressure (mmHg) by Group and Time Point

Time Point	Control Group Median (Range)	ESPB Group Median (Range)	P value
Preoperative	90.5 (84.0–97.0)	90.5 (84.0–96.0)	0.795
15 min post-intubation	98.5 (92.0–104.0)	96.0 (91.0–103.0)	0.016*
30 min intraoperative	101.0 (96.0–106.0)	98.0 (93.0–106.0)	0.004*
45 min intraoperative	98.5 (94.0–105.0)	96.5 (92.0–104.0)	0.030*
Post-extubation	103.5 (100.0–108.0)	102.0 (95.0–107.0)	0.002*

Data with non-normal distribution are expressed as median (range) and compared using the Mann-Whitney U test. * p < 0.05, statistically significant.

Table 3- Intraoperative Heart Rate (beats/min) by Group and Time Point

Time Point	Control Group Median (Range)	ESPB Group Median (Range)	P value
Preoperative	76.5 (70–83)	76 (71–85)	0.346
15 min post-intubation	85.5 (78–92)	81 (77–92)	0.028*
30 min intraoperative	89 (81–95)	84 (79–94)	0.004*
45 min intraoperative	85 (80–92)	82 (78–92)	0.001*
Post-extubation	95.5 (90–103)	90.5 (81–100)	0.001*

Data with non-normal distribution are expressed as median (range) and compared using the Mann-Whitney U test. * p < 0.05, statistically significant.

Table 4- Postoperative Pain Scores (NRS) by Group and Time Point

Time Point	Control Group Median (Range)	ESPB Group Median (Range)	P value
2 hours post-operative	6 (4–8)	4.5 (2–8)	0.003*
6 hours post-operative	5 (3–6)	3 (2–6)	0.012*
24 hours post-operative	3 (2–5)	2 (1–5)	0.009*

NRS, Numeric Rating Scale (0 = no pain; 10 = worst imaginable pain). Data with non-normal distribution are expressed as median (range) and compared using the Mann-Whitney U test. * p < 0.05, statistically significant.

Table 5- Serum Interleukin-6 Concentrations (pg/mL) by Group and Time Point

Time Point	Control Group Median (Range)	ESPB Group Median (Range)	P value
Preoperative	10.07 (8.03–12.18)	9.81 (8.05–12.00)	0.478
Post-extubation	58.26 (52.18–64.36)	53.45 (46.27–88.89)	0.004*
6 hours post-operative	70.65 (60.94–80.36)	63.28 (50.57–75.94)	0.001*

24 hours post-operative	36.93 (28.05–48.05)	33.69 (24.49–43.56)	0.013*

IL-6, Interleukin-6. Data with non-normal distribution are expressed as median (range) and compared using the Mann-Whitney U test. * $p < 0.05$, statistically significant.

Discussion

The principal finding of this study is that bilateral ultrasound-guided ESPB, administered prior to anesthetic induction, significantly attenuated intraoperative hemodynamic perturbation, reduced postoperative pain intensity, and lowered serum IL-6 concentrations compared with general anesthesia alone in patients undergoing elective laparoscopic cholecystectomy. Because the two groups were well matched at baseline across all measured variables age, sex, BMI, and comorbidity burden, these outcome differences can reasonably be attributed to the block rather than to pre-existing participant characteristics [8-9].

The hemodynamic benefit of ESPB observed here is best understood in the context of the physiological stress imposed by laparoscopic cholecystectomy. Carbon dioxide pneumoperitoneum raises intra-abdominal pressure substantially, compresses the inferior vena cava, and, through CO_2 absorption and activation of the sympatho-adrenal axis, triggers catecholamine releases that manifests as tachycardia and arterial hypertension [10]. In the present cohort, MAP and heart rate rose progressively in both groups after intubation and throughout surgery; however, this rise was consistently and significantly smaller in the ESPB group at every time point from 15 minutes post-intubation through extubation. The most clinically relevant attenuation was observed at extubation, a moment of intense laryngeal and pharyngeal stimulation that routinely produces sharp sympathetic surges. That ESPB continued to blunt this response suggests the block provides analgesic coverage extending well beyond the operative period, attributable to the multilevel spread of bupivacaine within the erector spinae fascial plane, which reaches the dorsal and ventral rami of thoracolumbar spinal nerves and, through the rami communicants, may modulate sympathetic outflow [5]. These findings corroborate those of Forero et al. (2016), originally described the ESPB's extensive dermatomal spread and subsequent evidence of improved hemodynamic stability in laparoscopic abdominal procedures [11-12].

Importantly, the analgesic benefit was observed at first 24 hours, with lower pain scores recorded at all three postoperative intervals. The ESPB group recorded lower NRS scores at each time point, and although the absolute between-group differences narrowed over 24 hours, they remained statistically significant throughout. This durability is clinically meaningful: pain during the first 24 hours after laparoscopic cholecystectomy is the principal determinant of delayed discharge and early opioid consumption, and inadequate early analgesia is independently associated with chronic post-surgical pain [13].

The analgesic mechanism of ESPB in this context is likely multifactorial. Local anesthetic injected deep into the erector spinae muscle spreads cranially and caudally within the fascial plane, blocking somatic afferents from the thoracic dermatomes supplying the anterior abdominal wall and, potentially, sympathetic fibers traveling in the rami communicants, thereby attenuating the visceral component of laparoscopic pain [5,12]. The use of 0.25% bupivacaine at a total volume of 40 mL, 20 mL per side, appears to provide sufficient concentration and spread for analgesia extending at least 24 hours, consistent with the pharmacokinetic profile of bupivacaine in fascial plane blocks [11]. These pain findings are in keeping with a growing body of evidence supporting ESPB as an effective component of multimodal analgesia in laparoscopic abdominal surgery [9,12].

Perhaps the most novel aspect of this study is the quantification of ESPB's effect on the systemic inflammatory response, measured by serial serum IL-6 concentrations. IL-6 rose sharply in both groups after surgery, as expected following combined general anesthesia, surgical tissue trauma, and peritoneal CO_2 insufflation, and peaked at six hours before declining by 24 hours, a kinetic pattern well characterized in the laparoscopic cholecystectomy literature [9-10].

Crucially, peak IL-6 concentrations were significantly lower in the ESPB group at all three postoperative measurement points, with the greatest absolute between-group difference at the six-hour peak. The mechanism underlying this immunomodulatory effect is most plausibly indirect: by interrupting afferent nociceptive signals and attenuating the sympatho-adrenal response to surgical trauma, ESPB reduces the principal upstream stimulus for hepatic IL-6 synthesis [5,12]. A reduction in perioperative sympathetic activation diminishes catecholamine-driven macrophage activation and the subsequent cytokine cascade, of which IL-6 is a primary mediator [10].

Clinically, elevated perioperative IL-6 is related to complications such as immunosuppression, higher infection susceptibility, and prolonged hospital stays [9]. In other hand, IL-6 suppression observed in this study translates into tangible clinical benefits remains to be verified in larger, adequately powered trials. Interestingly, post-extubation IL-6 levels were far more variable in the ESPB group (46.27–88.89 pg/mL) than in the control group (52.18–64.36 pg/mL). This wider range suggests a heterogeneous inflammatory response among block recipients, likely reflecting variations in block quality, local anesthetic spread, or patient-specific inflammatory phenotypes an area that merits further study.

Several limitations of this study should be considered when interpreting these findings. We did not perform 24-hour postoperative monitoring. Furthermore, while the hemodynamic findings for MAP and heart rate were statistically significant, but not clinically significant. Additionally, the small sample size may also impact the results.

Future studies should incorporate larger sample sizes, extended follow-up, broader biomarker panels, and prospective assessments of opioid consumption and patient-reported recovery outcomes. The present findings nonetheless provide clinically useful evidence supporting the integration of bilateral thoracic ESPB into standard anesthetic protocols for elective laparoscopic cholecystectomy, consistent with the analgesic and anti-inflammatory goals of contemporary Enhanced Recovery After Surgery pathways [11-12].

Conclusion

Bilateral ESPB, administered prior to induction, significantly attenuated intraoperative hemodynamic perturbation, reduced postoperative pain intensity for at least 24 hours, and lowered serum IL-6 concentrations at all postoperative time points compared with general anesthesia only in patients undergoing elective laparoscopic cholecystectomy. These findings support the integration of bilateral ESPB into multimodal anesthetic protocols for this procedure and warrant further investigation in larger trials with extended follow-up.

Authors' contributions

FSP drafted the manuscript. FSP and AS contributed to data interpretation and manuscript revision. AA, SG, and TM provided critical input on clinical methodology and supervision. AS, AA, and FSP contributed to laboratory analysis, data validation, and visualization. FSP, AA, AS, and CW for data analysis. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Data availability

The datasets and materials generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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