Incidence of chronic postsurgical pain after cardiac surgery and the effect of bilateral erector spinae plane block: a randomized controlled trial

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ABSTRACT

Background The effects of the erector spinae plane (ESP) block on chronic postsurgical pain (CPSP) after cardiac surgery remain unclear. This study evaluated the efficacy of bilateral ESP block in reducing the incidence and severity of CPSP after cardiac surgery.

Methods This prospective, randomized, controlled, single-blind trial included 63 patients aged 18–80 years with American Society of Anesthesiologists physical status II–III, scheduled for elective cardiac surgery via median sternotomy. Participants received a bilateral ultrasound-guided ESP block or standard care without regional anesthesia. The primary outcome was the Brief Pain Inventory (BPI) score at 3 months postoperatively. Secondary outcomes included morphine consumption in the first 24 hours; Numerical Rating Scale (NRS) scores during rest/activity at 0, 3, 6, 12, and 24 hours; BPI scores at 6 months postoperatively; and Douleur Neuropathique 4 (DN4) and Hospital Anxiety and Depression Scale (HADS) scores at 3 and 6 months postoperatively.

Results The BPI scores of the two groups did not differ significantly at 3 months postoperatively (median (IQR): 0(26) vs 12 (31), p=0.166). However, 24 hours postoperative morphine consumption (8 mg vs 10.5 mg, p<0.001) and NRS scores at multiple time points were significantly lower in the ESP block group. No significant differences were observed between the groups in terms of the BPI, DN4, or HADS scores at three or 6 months.

Conclusions The ESP block effectively reduced acute pain and opioid consumption; however, it had no significant effect on the incidence or severity of CPSP at 3 and 6 months.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Chronic postsurgical pain (CPSP) after cardiac surgery affects up to one-third of patients, posing a significant clinical challenge.

⇒ The erector spinae plane (ESP) block is widely used for managing acute pain; however, its long-term effects on CPSP remain unclear.

WHAT THIS STUDY ADDS

⇒ This study revealed that although bilateral ESP block significantly reduced acute postoperative pain and opioid consumption, it did not significantly impact the incidence or severity of CPSP at 3 or 6 months after cardiac surgery.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings underscore the necessity of developing multimodal approaches beyond regional anesthesia to mitigate CPSP after cardiac surgery. Large-scale, multicenter trials must be conducted to explore alternative or adjunctive strategies for enhancing long-term pain outcomes in this population.

INTRODUCTION

Chronic postsurgical pain (CPSP) after cardiac surgery affects approximately 30% of patients at 3 months and 15% at 12 months postoperatively, significantly impacting their quality of life[1 2] and potentially leading to cardiac and pulmonary complications.[3] Acute postoperative pain is a risk factor for chronic pain; thus, patients experiencing moderate postoperative pain are at an increased risk of developing CPSP.[4] Perioperative multimodal, opioid-sparing pain management is recommended by the Enhanced Recovery After Cardiac Surgery (ERACS) guidelines.[5] A joint Consensus Statement suggests that chest wall regional analgesia can be an effective component of a multimodal approach for managing perioperative pain.[6] However, the impact of these techniques on CPSP remains unclear.

The erector spinae plane (ESP) block has emerged as a promising technique for pain management in various surgical procedures,[7] with several studies demonstrating its efficacy in managing pain following cardiac surgery.[8 9] The ESP block has been identified as the most effective treatment among single-shot ultrasound-guided regional anesthesia techniques.[10] However, apart from an ongoing multicenter study (NCT06382077), research examining the efficacy of the ESP block in managing CPSP is scarce.[11] Therefore, this study aimed to explore the potential impact of a single bilateral ESP block on the development of CPSP 3 months after cardiac surgery, as a hypothesis-generating approach within the broader context of multimodal perioperative pain management. The study hypothesis posited that 'The Brief Pain Inventory (BPI) scores in the third postoperative month will differ significantly between patients who underwent open cardiac surgery with and without the ESP block.'

METHODS

Study design

The study was registered with ClinicalTrials.gov (NCT06315959; principal investigator: (BD); Registration Date: (March 18, 2024)) before patient enrollment. The first patient was enrolled on April 1, 2024. This study adhered to the principles of the Declaration of Helsinki (64th World Medical Association General Assembly, Fortaleza, Brazil, October 2013). The manuscript was prepared in accordance with the 2010 Consolidated Standards of Reporting Trials statement.[12]

Participants

Patients scheduled for elective on-pump open cardiac surgery at a tertiary university hospital between April 2024 and August 2024 were eligible for this study. Written informed consent was obtained from all participants prior to enrollment. Eligible patients were aged 18–80 years and had an American Society of Anesthesiologists (ASA) Physical Status Score of II or III, provided they could use a patient-controlled analgesia (PCA) device. Exclusion criteria included chronic pain syndrome or long-term opioid use (greater than 4 weeks); hypersensitivity to opioids, non-steroidal anti-inflammatory drugs (NSAIDs), or local anesthetics; a history of alcohol or substance abuse; contraindications to regional anesthesia (such as injection site or systemic infections, anticoagulant use, or bleeding disorders); a failed block in the dermatomal examination; obstructive sleep apnea syndrome (apnea-hypopnea index >5/hour); left ventricular ejection fraction <30%; limited communication owing to severe neuropsychiatric disorders (psychosis, dementia); and significant hepatic and renal disorders were excluded. In addition, patients undergoing emergency and redo surgeries, pregnant and lactating patients, and those who were unlikely to be extubated within the first 6 hour postoperatively were also excluded.

Randomization, allocation concealment, and blinding

Participant eligibility was assessed by study physicians (BD and ESO). Eligible patients were randomly allocated to either the ESP block group (n=33) or the control group (n=34). Randomization was conducted by an anesthesiology resident not involved in patient follow-up. A 1:1 allocation ratio was used, with block randomization based on a permuted block size of 4, generated via the 'Research Randomizer' web-based tool to ensure proper allocation concealment.[13] Each group assignment was placed in a sequentially numbered, opaque, and sealed envelope, prepared in advance, and securely maintained by the principal investigator (BD) until the day of surgery. 1 hour before surgery, a technician not involved in the study requested an independent individual to select an envelope, thereby determining group assignment. The ESP block was performed in the operating room by an anesthesiologist not involved in the study 30 min prior to surgery. To ensure block quality and procedural standardization, the block was administered by an experienced anesthesiologist who had performed at least 30 ESP blocks. Patient blinding was not feasible due to the timing of the ESP block; however, investigators, care providers, outcome assessors, statisticians, and surgeons remained blinded to minimize potential bias.

Block procedure

The ESP block was performed after monitoring (electrocardiography, non-invasive arterial pressure, and peripheral oxygen saturation) prior to surgery. Following the initiation of lactated Ringer's infusion via a 20–22 G intravenous cannula, 0.03 mg/kg of intravenous midazolam was administered to achieve a Ramsay Sedation Score of 2 (awake, calm, and responsive to surroundings). Oxygen was administered through a nasal cannula at a flow rate of 3 L/min.

Ultrasound-guided ESP block

The area between the bilateral scapulae at the thoracic vertebrae level was prepared according to asepsis and antisepsis protocols, with the patient in a sitting position. A convex ultrasound probe (8–13 MHz, GE LOGIQ V1 Ultrasound System) covered with a sterile protective plastic sheath was positioned sagittally, with the probe marker oriented in the craniocaudal direction and approximately 2–3 cm lateral to the T4 vertebra. The erector spinae muscle was visualized above the transverse process, and the following structures were identified from superficial to deep: skin, subcutaneous tissue, trapezius muscle, rhomboid muscle, erector spinae muscle, and transverse process. Subsequently, 2 mL of 2% lidocaine (Aritmal, Vem İlaç, Tekirdag, Türkiye) was injected into the skin and subcutaneous tissues. A block needle (21 G, 80 mm short-bevel; Stimuplex Ultra 360, B. Braun, Melsungen AG, Melsungen, Germany) was advanced into the plane between the erector spinae muscle and the transverse process from cranial to caudal. Correct needle placement was confirmed by injecting 1–2 mL of 0.9% normal saline. Following hydrodissection, 30 mL of 0.25% bupivacaine (Marcaine, AstraZeneca, North Ryde, NSW) was injected into this plane, with the spread of the local anesthetic agent observed in both the cranial and caudal directions. This procedure was repeated on the contralateral side (online supplemental material 1). The maximum dose of 2.5 mg/kg (based on ideal body weight) was not exceeded. Sensory assessment was performed 30 min post-block using ice tubes, categorizing responses as normal, reduced, or absent. A successful block was defined as a complete loss or reduction in cold sensation, whereas normal cold perception was classified as a failed block.

Anesthesia management

Anesthesia was induced using propofol (0.5–2 mg/kg), remifentanil (0.5 μg/kg intravenous bolus and 0.3 μg/kg/min infusion), and rocuronium (1 mg/kg intravenous) for endotracheal intubation after invasive arterial pressure monitoring. Rocuronium boluses (0.1–0.2 mg/kg intravenous) were given to maintain a Train of Four count of 1–2. Anesthesia was sustained with a mixture of 60% O_2/air, age-adjusted 1 minimum alveolar concentration sevoflurane, and remifentanil (0.1–0.3 μg/kg/min), titrated to keep hemodynamics within ± 20% of baseline. The bispectral index was targeted between 40 and 60. A right internal jugular central venous catheter was inserted for hemodynamic monitoring. Volume-controlled ventilation (Dräger Perseus A500; tidal volume: 7–8 mL/kg; I:E ratio: 1:2; respiratory rate adjusted to maintain $EtCO_2$ at 30–35 mm Hg) was initiated. Glycemia and fluid intake were managed as required. Extubation was performed within 6 hours per standard intensive care unit (ICU) protocols following the ERACS guidelines. Patients who underwent delayed extubation were excluded from the study.

Analgesia management

During the preoperative consultation, held 1 day before surgery, patients were educated about the Numerical Rating Scale (NRS), which ranges from 0 to 10, where 0 indicates 'no pain' and 10 denotes 'the worst pain imaginable.' They were instructed on how to use the scale to evaluate pain intensity during the

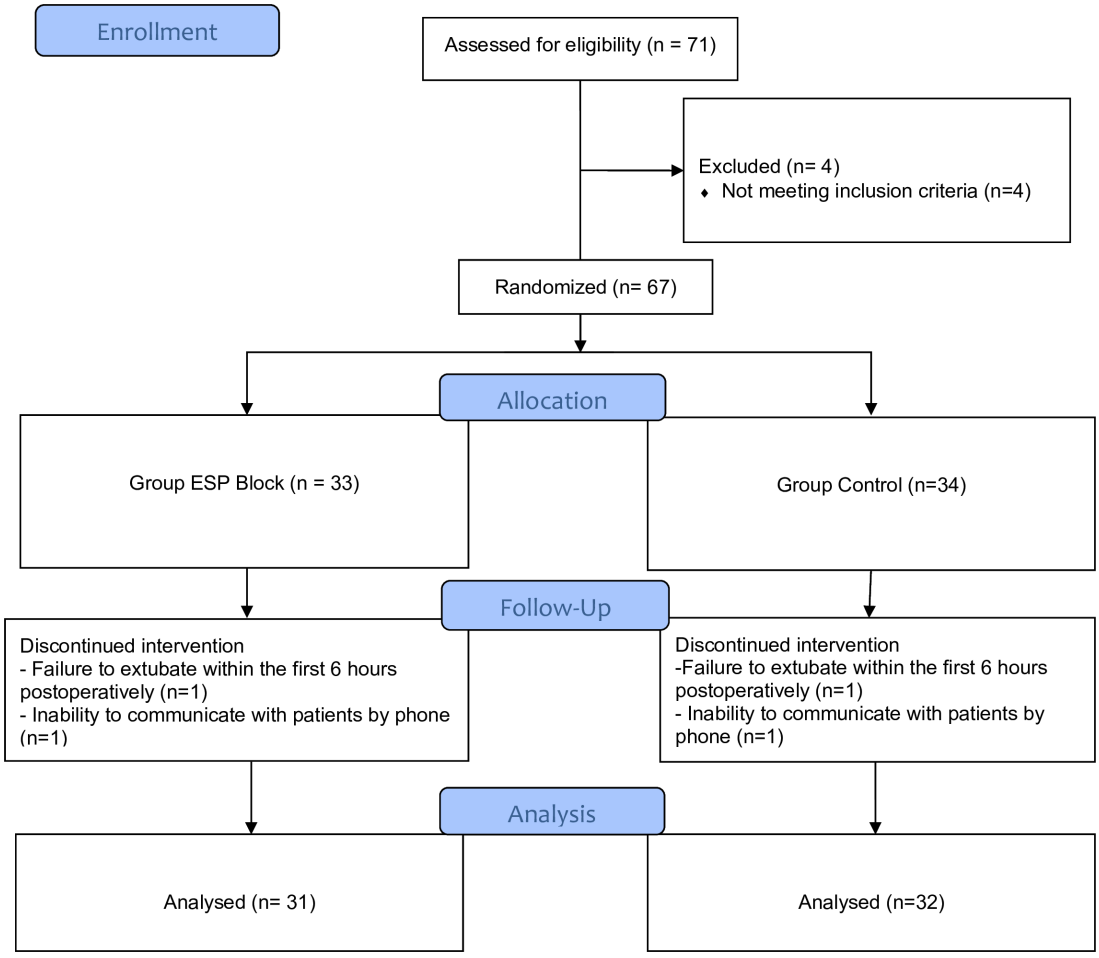

Figure 1 CONSORT flow diagram of the participants. CONSORT, Consolidated Standards of Reporting Trials; ESP, erector spinae plane.

postoperative period, and the use of the PCA device was explained. Patients were advised to request opioids via the PCA device when their NRS scores exceeded 3 at rest. All patients received 0.05 mg/kg of intravenous morphine intraoperatively and 1 g of intravenous paracetamol 30 min before the procedure's conclusion. The administration of intravenous paracetamol was continued every 8 hours postoperatively. Following extubation, patients were provided with PCA (BodyGuard 575 Pain Manager, Caesarea Medical Electronics, Germany) with the following parameters: a demand dose of 20 µg/kg morphine, a 10 min lockout interval, and a 4-hour limit not exceeding 80% of the total dose. Ibuprofen and/or 10 mg of intravenous ketamine and/or 25–50 μg of fentanyl were administered in the recovery unit when rescue analgesia was necessary (NRS score ≥4 at rest despite PCA demands). On discharge, patients were prescribed oral non-opioid analgesics, typically paracetamol or NSAIDs, based on individual clinical factors such as renal function, liver function, and the presence of contraindications including acute kidney injury or hepatic impairment.

Management of postoperative nausea and vomiting

Intravenous dexamethasone (8 mg) was routinely administered before induction as prophylaxis for postoperative nausea and vomiting (PONV). Additionally, 0.15 mg/kg of intravenous ondansetron was administered 20 min before the surgery ended. PONV severity was assessed using a verbal scale (0=none, 1=mild nausea, 2=moderate nausea, 3=one episode of vomiting, and 4=multiple episodes of vomiting). Patients with a score ≥3 received an additional 4 mg of intravenous ondansetron.

Postoperative chronic pain assessment

Chronic pain assessment was conducted through face-to-face interviews (or via telephone when in-person meetings were not possible) at postoperative months 3 and 6. Chronic pain was defined as pain that develops or increases following the surgical procedure, is localized to the surgical area, persists for at least 3 months, and is distinct from preoperative sensations, according to the International Classification of Diseases-11 (ICD-11) criteria.[14] Patients meeting this criterion were classified as having chronic pain. The Turkish version of BPI was used to assess pain intensity and interference.[15]

BPI was evaluated in two sections. The first section comprised questions measuring pain intensity, scored on a scale of 0–10 (0=no pain, 10=worst pain imaginable). The scores from four questions assessing 'worst pain,' 'least pain,' 'average pain,' and 'current pain' levels were summed to obtain an overall score. The second section comprised seven questions evaluating the impact of pain on daily function, with scores ranging from 0 to 10. Patients assessed the degree to which pain affected their 'general activities,' 'emotional state,' 'walking ability,' 'deep breathing and coughing exercises,' 'relationships with others,' 'sleep,' and 'enjoyment of life.' The Douleur Neuropathique 4 (DN4) score was used to assess pain characteristics at 3 and 6 months postoperatively. The Hospital Anxiety and Depression Scale (HADS-A/

HADS-D) was used to evaluate patients' anxiety and depression statuses. Patients with a DN-4 score ≥4 were considered to have neuropathic pain.

Outcomes

The primary outcome was the BPI score at 3 months postoperatively. Secondary outcomes included morphine consumption in the first 24 hours; NRS scores during rest and activity at 0, 3, 6, 12, and 24 hours; number of patients requiring rescue analgesia; PONV scores; extubation time; length of ICU stay; length of hospital stay; BPI score at 6 months postoperatively; and DN4, HADS-A, and HADS-D scores at 3 and 6 months postoperatively. Preoperative BPI, HADS-A, and HADS-D scores were also recorded. Additionally, block-related complications (hematoma, infection, pneumothorax, and local anesthetic toxicity) and opioid-related side effects (pruritus, fatigue, sedation, and respiratory depression) were documented.

Sample size calculation

Sample size estimation was based on cumulative BPI scores at 3 months obtained from a preliminary pilot study involving 10 patients per group who underwent elective, on-pump, open cardiac surgery via full median sternotomy. Using G*Power software (V.3.1.9.7, Düsseldorf, Germany), it was determined that a minimum of 29 patients per group would be required to detect a statistically significant difference, with an effect size of 0.76, a two-sided alpha level of 0.05, and a power (1−β) of 80%. In the pilot data, the mean±SD deviation of BPI scores was 7.8±10.64 in the ESP group and 17.7±15.16 in the control group. To account for potential dropouts or missing data, the sample size was increased by 20%, resulting in a total enrollment of 67 patients.

Statistical analysis

All statistical analyses were conducted using the SPSS software V.27 (IBM). Descriptive statistics for categorical variables are presented as frequencies (n) and percentages (%). Pearson's χ^2 test or Fisher's exact test was used as appropriate to compare categorical variables. The Shapiro-Wilk test was employed to evaluate the normality of the numerical data distributions. Numerical variables are presented as mean±SD deviation for normally distributed data and as median values with IQRs for non-normally distributed data.

The independent samples t-test and Mann-Whitney U test were used to compare normally and non-normally distributed data, respectively. The Kaplan-Meier method was applied to estimate survival probabilities over time, and the log-rank and Breslow tests were used to assess differences between the survival curves. Statistical significance was set at $p<0.05$, with all hypotheses undergoing two-tailed tests.

RESULTS

Four of the 71 patients assessed for eligibility were excluded for not meeting the inclusion criteria. One patient from each group discontinued participation during the follow-up period because of failure to extubate within the first 6 hours postoperatively (n=1) and inability to communicate with the patient by phone (n=1). Consequently, data from 63 patients (ESP block group, n=31; control group, n=32) were analyzed (figure 1).

No significant differences were observed between the groups regarding demographic and clinical characteristics, including sex, age, body mass index (BMI), ASA scores, comorbidities, surgical parameters, pleural protection, and hospital stay (table 1).

Table 1 Demographic profile and clinical characteristics of patients

	Group ESP block (n=31)	Group control (n=32)	P value
Sex, n (%)			
Female	14 (45.2)	11 (34.4)	0.44
Male	17 (54.8)	21 (65.6)	
Median age (IQR) in years	67 (11)	66.5 (5.2)	0.75
Mean BMI (SD) in kg/m^2	29.40 (4.73)	28.46 (4.58)	0.42
ASA score, n (%)			
ASA II	2 (6.5)	0 (0)	0.14
ASA III	29 (93.5)	32 (100)	
Comorbidities, n (%)			
Cardiovascular system*	12 (38.7)	7 (21.9)	0.24
Endocrine system†	2 (6.5)	5 (15.6)	
>1 more system	17 (54.8)	20 (62.5)	
Median EF (IQR) in %	55 (10)	52.5 (16.2)	0.76
Type of surgery, n (%)			0.35
CABG	19 (61.3)	20 (62.5)	
AVR	4 (12.9)	3 (9.4)	
CABG+AVR	1 (3.2)	4 (12.5)	
MVR	2 (6.5)	2 (6.3)	
AVR+MVR	1 (3.2)	0 (0)	
CABG+MVR	2 (6.5)	0 (0)	
Left atrial mass (myxoma)	2 (6.5)	0 (0)	
ASD+pulmonary venous return anomaly	0 (0.0)	1 (3.1)	
Bentall procedure	0 (0)	1 (3.1)	
Aortic aneurysm	0 (0)	1 (3.1)	
Median sternal retraction distance (IQR) in cm	14 (2)	15 (1.2)	0.08
Pleura protection, n (%)	15 (48.4)	21 (65.6)	0.2
Median duration of surgery (IQR) in min	225 (45)	250 (36.2)	0.11
Median duration of perfusion (IQR) in min	110 (20)	122.5 (53.7)	0.15
Median duration of aortic cross-clamp (IQR) in min	70 (35)	85 (38.7)	0.15
Median postoperative length of stay in the surgical intensive care unit (IQR) in days	3 (2)	3 (1)	0.41
Median postoperative length of stay in the hospital (IQR) in days	8 (3)	8.5 (2.2)	0.89
Median time of extubation (IQR) in h	5 (2)	5 (2)	0.48

Continuous variables are presented as median (IQR) or mean±SD, and categorical variables are presented as counts (%).
*Hypertension, coronary artery disease, valvular heart disease, heart failure.
†Type 1 diabetes, type 2 diabetes, goiter.
ASA, American Society of Anesthesiologists; ASD, atrial septal defect; AVR, aortic valve replacement; BMI, body mass index; CABG, coronary artery bypass graft; EF, ejection fraction; ESP, erector spinae plane; MVR, mitral valve replacement.

The incidence of CPSP at 3 months was 38% (12/31) and 53% (17/32) in the ESP block and control groups, respectively (p=0.31). At 6 months, the incidence rates were 38% (12/31) and 50% (16/32) in the ESP block and control groups, respectively (p=0.45) (figure 2).

Median (IQR) preoperative BPI scores were comparable between the groups for Pain Severity (0 (0) vs 0 (0), p=0.67), Pain Interference (0 (0) vs 0 (0), p=0.64), and Total Scores (0 (0) vs 0 (0), p=0.64). However, the ESP block group exhibited lower BPI Pain Severity (0 (9) vs 5.5 (12), p=0.07), Pain

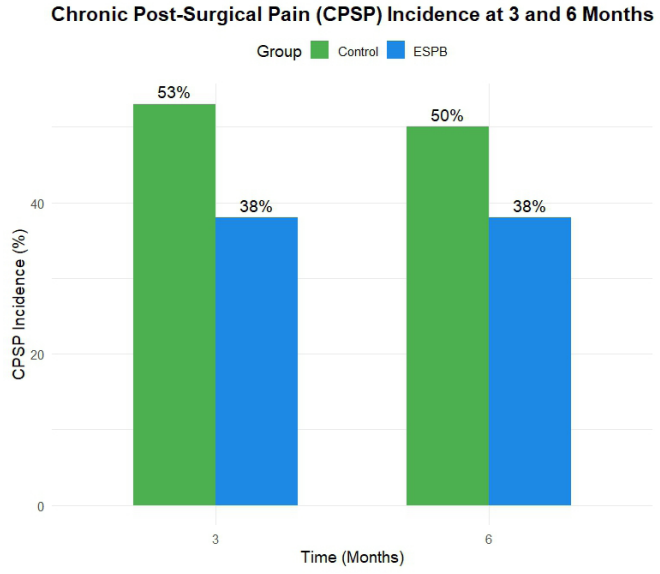

Figure 2 CPSP incidence at 3 and 6 months after cardiac surgery. ESPB, erector spinae plane block.

Interference (0 (17) vs 5 (19.75), p=0.36), and Total Scores (0 (26) vs 12 (31), p=0.16) at 3 months postoperatively; these differences were not statistically significant. At 6 months, the BPI Pain Severity scores in the ESP block group were lower (0 (7) vs 4 (10), p=0.06), along with Pain Interference (0 (10) vs 3.5 (10), p=0.54) and Total Scores (0 (19) vs 7.5 (22), p=0.2). Again, these differences were not significant (figure 3).

Median (IQR) morphine consumption over 24 hours (8 mg (4)) was significantly lower in the ESP block group than in the control group (10.5 mg (4); p<0.001). Rescue analgesia was required by 16.1% and 21.9% of the patients in the ESP block and control groups, respectively; however, this difference was not statistically significant (p=0.75) (table 2).

Median (IQR) resting NRS scores were significantly lower in the ESP block group at 0 hour (3 (1) vs 3 (1), p <0.01), 3 hours (2 (1) vs 3 (0.25), p=0.01), 6 hours (2 (1) vs 3 (1), p=0.001), and 12 hours (2 (1) vs 2 (1), p=0.04). Similarly, the median (IQR) activity NRS scores were significantly lower in the ESP block group at 3 hours (3 (2) vs 4 (2), p <0.01) and 6 hours (2 (1) vs 3 (1), p=0.03) (table 3).

The median (IQR) PONV scores at 0 hour (1 (1) vs 2 (1), p=0.03), 12 hours (0 (1) vs 1 (0), p<0.001), and 24 hours were significantly lower in the ESP block group (0 (1) vs 1(0), p<0.001) (online supplemental material 2).

The incidence of neuropathic pain was similar in both groups at 3 months (ESP block, 9.7%; control, 12.5%, p=0.72) and 6 months (ESP block, 3.2%; control, 12.5%, p=0.17), indicating no significant differences (table 2). Median (IQR) DN4 scores were lower in the ESP block group at 6 months (0 (1) vs 0.5 (2.2)); however, this difference was not significant (p=0.07) (online supplemental material 3).

No significant differences were observed between the groups at any time point, including preoperatively (HADS-A, p=0.48; HADS-D, p=0.05) and during follow-up (p>0.05), in HADS scores (online supplemental material 4). The mean survival time was comparable between the ESP block (20.71 hours) and control (19.5 hours) groups, with no significant differences observed in the survival curves (log-rank test, p=0.58; Breslow test, p=0.59) (online supplemental material 5).

DISCUSSION

This study evaluated the effects of the ESP block on acute and chronic pain following cardiac surgery. Compared with the control group, the ESP block group demonstrated a significant reduction in acute pain parameters, including lower morphine consumption and NRS scores. However, no significant

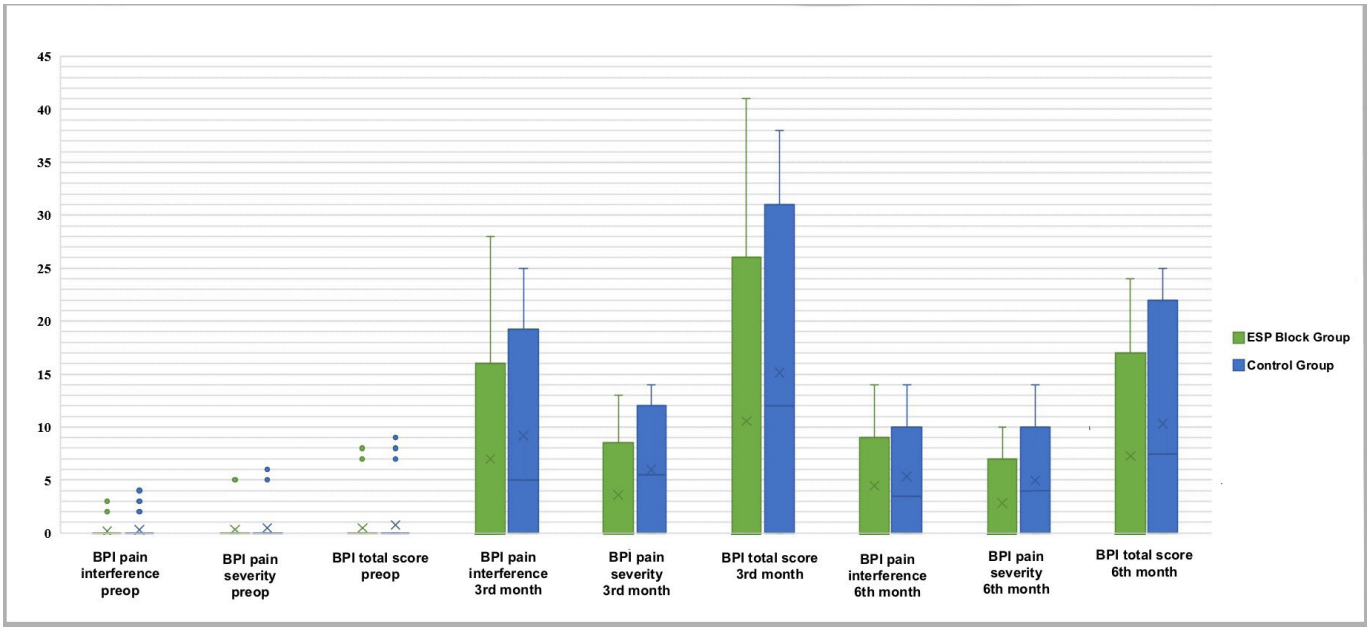

Figure 3 Comparison of Brief Pain Inventory (BPI) scores between the ESP block and control groups. This figure illustrates the BPI pain interference, pain severity, and total scores preoperatively and at 3 and 6 months postoperatively in the ESP block and control groups. The scores are presented as median values with IQR. The ESP block group demonstrated lower scores across all domains at 3 and 6 months, although the differences were not statistically significant. ESP, erector spinae plane.

Table 2 Postoperative analgesic consumption and neuropathic pain incidence

	Group ESP block (n=31)	Group control (n=32)	P value
Median postoperative cumulative intravenous morphine consumption first 24 hours (IQR) in mg	8 (4)	10.5 (4)	**<0.001**
Patients given rescue analgesic in the first 24 hours, n (%)	5 (16.1)	5 (16.1)	0.75
Patients with neuropathic pain at the 3rd month, n (%)	3 (9.7)	4 (12.5)	0.72
Patients with neuropathic pain at the 6th month, n (%)	1 (3.2)	4 (12.5)	0.17

Continuous variables are presented as median (IQR), and categorical variables are presented as counts (%). The statistically significant difference is highlighted in bold, p<0.05.
ESP, erector spinae plane.

differences were observed between the groups regarding the incidence of CPSP or scores on the BPI, DN4, and HADS at 3 and 6 months postoperatively.

Previous studies suggest potential long-term benefits of ESP blocks. Guven Kose *et al*[16] demonstrated that the ESP block effectively reduced myofascial pain at the 6 week follow-up. Similarly, 53% of patients in a recent retrospective study on ESP blocks for cancer-related chronic pain reported pain relief.[17] Genc *et al* found that the ESP block significantly reduced the VAS scores at 3 months postoperatively among patients who underwent breast cancer surgery[18]; however, they did not use an objective measurement tool such as the BPI score. To date, no randomized controlled trial has specifically evaluated the impact of the ESP block on CPSP following cardiac surgery. Our findings are consistent with those of Toscano *et al*, who, in an observational study of minimally invasive cardiac surgery using the BPI, reported no significant difference in chronic pain outcomes among patients receiving continuous ESP block, intravenous morphine, or a serratus anterior plane block.[19] Similarly, Moorthy *et al*, in a randomized trial comparing ESP and paravertebral catheters after minimally invasive thoracic surgery, observed better early recovery with the ESP block but found no differences in BPI scores or CPSP incidence at 3 months.[20] In contrast, Wiech *et al* used the Neuropathic Pain Symptom Inventory (NPSI) to evaluate neuropathic pain in an observational study and reported favorable results with the ESP block. However, it is important to note that the NPSI does not capture the broader dimensions of chronic pain.[21] Although Yuce *et al*, in a retrospective study, suggested that the ESP block was effective for chronic pain after cardiac surgery, they used the Prince Henry Hospital Pain Score, which is primarily designed for acute pain assessment and may not adequately reflect the characteristics of chronic pain.[22]

Table 3 NRS pain scores at rest and activity in the groups at different time points

	Group ESP block (n=31)	Group control (n=32)	P value
Median (IQR) NRS_{rest}			
Extubation	3 (1)	3 (2)	**<0.01**
3rd hour	2 (1)	3 (0.2)	**0.01**
6th hour	2 (1)	3 (1)	**0.001**
12th hour	2 (1)	2 (1)	**0.04**
24th hour	1 (1)	2 (0.5)	0.23
Median (IQR) $NRS_{activity}$			
Extubation	4 (2)	5 (2)	0.11
3rd hour	3 (2)	4 (2)	**<0.01**
6th hour	2 (1)	3 (1)	**0.03**
12th hour	2 (2)	3 (1.2)	0.14
24th hour	2 (1)	3 (1.2)	0.1

Continuous variables are presented as median (IQR). The statistically significant difference is highlighted in bold, p<0.05.
ESP, erector spinae plane; NRS, Numeric Rating Scale.

The incidence of CPSP in the present study was consistent with previously reported rates. The prevalence of CPSP after cardiac surgery ranges from 20% to 80%,[11 23] which may be attributed to inconsistencies in its definition and assessment methods. The recent classification set forth by the ICD-11 is widely accepted as the standard definition.[14] The present study adhered to that definition to ensure methodological consistency in the assessments. We found no significant difference in the incidence of neuropathic pain between the ESP block and control groups at both 3 and 6 months postoperatively. These findings are in line with previous randomized and observational studies suggesting that the type of regional anesthesia technique may not substantially influence the long-term development of CPSP.[20 24] Chronic pain involves complex mechanisms, including peripheral and central sensitization, neuroinflammation, and structural changes in the nervous system, necessitating prolonged or multimodal interventions.[25] Additionally, variations in surgical techniques, preoperative risk factors, and individual pain sensitivity may have influenced the results. Taken together, the results support the view that CPSP is a multifactorial condition, and a single regional intervention such as the ESP block may have limited long-term impact on its prevention.[26] Further research is warranted to optimize regional anesthesia strategies, given the high prevalence of CPSP and its significant impact on postoperative recovery and quality of life. Large-scale, multicenter trials with extended follow-up durations and standardized outcome measures are needed to determine the most effective interventions for mitigating chronic pain in patients undergoing cardiac surgery.

The requirement for continuous administration of ESP blocks was another important consideration. Continuous infusion, rather than a single-shot technique, yields long-term efficacy of the ESP block, particularly in thoracic and breast surgeries. A catheter-based ESP approach may have produced different results in the present study. However, our findings are consistent with those of Toscano *et al*, who reported no significant difference in chronic pain outcomes between patients receiving continuous ESP block, intravenous morphine, or serratus anterior plane block.[19] Similarly, Moorthy *et al*, in a study comparing continuous ESP and paravertebral catheters after minimally invasive thoracic surgery, found no difference in BPI scores or CPSP incidence at 3 months.[20] Given these conflicting findings in the literature, future studies should explore whether extending the duration of ESP block through continuous infusion or combining it with other fascial plane blocks may enhance its effectiveness in preventing CPSP following cardiac surgery.

The present study had some limitations. First, its generalizability is limited as it was a single-center study, necessitating a larger multicenter trial to validate these findings. Second,

although the follow-up period of 6 months aligns with the ICD-11 definition of CPSP, a longer follow-up period (up to 1 year) may provide more comprehensive insights into the long-term effects of the ESP block. Third, potential confounding factors, such as variations in surgical techniques and psychological factors (eg, anxiety or depression), may have affected the outcomes. While validated pain assessment tools such as the BPI and HADS were used, incorporating additional objective measures such as quantitative sensory testing or biomarkers could have provided further mechanistic insights. Fourth, patient-specific variability, including genetic predisposition to chronic pain and differences in pain perception, may have influenced the responses to the ESP block. Fifth, a notable limitation of our study is the lack of data on postdischarge analgesic use at 3 and 6 months. Information regarding continued use of analgesics—including opioids and neuropathic pain medications such as gabapentin or pregabalin—was not systematically recorded. These medications may influence the incidence and severity of CPSP and could confound the interpretation of long-term pain outcomes. Given the multifactorial nature of CPSP, our findings should be interpreted as exploratory and hypothesis-generating, highlighting the potential—though not exclusive—role of the ESP block in its prevention. In this study, neuropathic pain was assessed using the DN4 questionnaire, a validated screening tool for identifying neuropathic components of pain. However, in patients who did not meet the DN4 criteria, the specific nature of their pain (eg, somatic, visceral, or referred) was not systematically evaluated. Lastly, given the effect size used in the sample size estimation, the study may be underpowered to detect smaller but clinically meaningful differences. This potential limitation should be taken into account when interpreting the results.

In conclusion, while this study aimed to evaluate the potential of the ESP block in reducing CPSP, we recognize that the development of chronic pain is multifactorial and unlikely to be fully prevented by a single intervention. Our findings support the growing consensus that effective CPSP prevention will likely require multimodal and sustained analgesic strategies, addressing both peripheral and central pain mechanisms. In addition to these approaches, a broader multidisciplinary strategy may be necessary, incorporating pharmacological treatments for chronic pain, interventional techniques such as peripheral nerve stimulation or spinal cord stimulation, physical therapy, and psychological support. Transitional pain services can play a critical role in bridging the gap between acute and chronic pain, offering timely interventions that may help prevent the chronification of pain.[27] Therefore, this study should be viewed as a hypothesis-generating effort to guide future research on the role of the ESP block within a broader perioperative pain management framework.

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