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Original Research Article

A randomized comparison of erector spinae and paravertebral blocks for postoperative analgesia in minimally invasive mitral valve replacement surgery

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Abstract

Background and Aims: Optimizing postoperative analgesia is critical for enhancing recovery after cardiac surgery. The thoracic paravertebral plane block (PVPB) is a well-established regional technique, while the erector spinae plane block (ESPB) is a newer fascial plane block that may offer comparable or superior analgesia. This study aims to compare the opioid-sparing efficacy and recovery outcomes of ultrasound-guided ESPB versus PVPB in patients undergoing minimally invasive mitral valve replacement (MIMVR) within an Enhanced Recovery After Surgery (ERAS) protocol.

Materials and Methods: In this double-blind randomized controlled trial, 80 ASA III adults scheduled for MIMVR via right mini-thoracotomy were randomly assigned (1:1) to receive either ESPB or PVPB at the T5 level, with 20 mL of 0.25% bupivacaine. The primary outcome was total 24-hour postoperative morphine consumption. Secondary outcomes included intraoperative fentanyl use, time to first morphine request, pain scores, time to extubation and ambulation, ICU and hospital length of stay, and adverse events**.**

Results: The ESPB group required significantly less morphine over 24 hours (11.9 ± 1.3 mg vs 14.5 ± 1.2 mg; $p < 0.001$) and less intraoperative fentanyl (263.8 ± 17.3 µg vs 303.6 ± 20.2 µg; $p < 0.001$). Time to first morphine request was longer in the ESPB group (7.2 ± 1.1 hours vs 5.8 ± 1.3 hours; $p < 0.001$). Pain scores were lower in the ESPB group from the 4th to the 18th postoperative hour ($p < 0.001$). Extubation occurred earlier in the ESPB group (3.6 ± 0.9 hours vs 5.4 ± 0.8 hours; $p < 0.001$), and ambulation occurred sooner (7.4 ± 1.0 hours vs 9.1 ± 1.0 hours; $p < 0.001$). No adverse effects were reported.

Conclusions: Ultrasound-guided ESPB provides superior opioid-sparing analgesia and facilitates faster recovery compared to PVPB in patients undergoing minimally invasive mitral valve replacement, supporting its inclusion in ERAS cardiac protocols.

Keywords: Erector spinae plane block, Paravertebral plane block, Opioid consumption, minimally invasive mitral valve replacement.

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1. Introduction

Minimally invasive mitral valve surgery includes a variety of techniques that leverage modified visualization, specialized instrumentation, and advanced perfusion systems, all designed to minimize surgical incisions. These innovations aim to reduce operative trauma, operative time, blood loss, and the need for transfusions.[1] This surgical approach provides several benefits, including reduced postoperative pain, improved respiratory function, and accelerated rehabilitation, leading to earlier weaning from intensive care and shorter overall hospital stays.[2-4]

Postoperative pain following cardiac surgery typically peaks during the first 24 hours and gradually diminishes in the following days. Although minimally invasive cardiac surgery is designed to be less traumatic, patients still experience moderate to severe pain due to the thoracotomy incision and chest tube insertion. Additionally,

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cardiopulmonary bypass contributes to increased pain intensity through its systemic inflammatory effects.[5]

The American Society of Anaesthesiologists (ASA) recommends a multimodal analgesic strategy for perioperative pain control, which aims to optimize patient comfort while reducing opioid requirements.[6] Recently, there has been a significant shift toward less invasive surgical techniques, accompanied by advanced, opioid-sparing regional anaesthesia methods within multimodal pain management frameworks, all designed to enhance recovery and reduce perioperative complications.

Enhanced Recovery After Surgery (ERAS) protocols have recognized the thoracic paravertebral plane block (PVPB) as a safe and effective alternative to thoracic epidural analgesia, offering similar pain control with fewer adverse effects. The erector spinae plane block (ESPB), first described by Forero in 2016, has since gained considerable clinical attention due to its simplicity, safety, and versatility in providing thoracic analgesia for a wide range of surgical procedures.[7]

In light of these advancements, several recent trials have compared PVPB and ESPB in thoracic surgery, reflecting the growing clinical adoption of ESPB as part of multimodal analgesic strategies.[8] This randomized controlled trial aimed to specifically assess whether ultrasound-guided ESPB offers superior opioid-sparing analgesia, enhanced recovery outcomes, and a more favorable safety profile compared to PVPB in patients undergoing ERAS-guided minimally invasive mitral valve replacement.

2. Materials and Methods

This randomized controlled trial was designed to evaluate the efficacy and safety of two regional anaesthesia techniques, the erector spinae plane block (ESPB) and the paravertebral plane block (PVPB), in patients undergoing minimally invasive mitral valve replacement (MIMVR) as part of an Enhanced Recovery After Surgery (ERAS) protocol. The trial was conducted at a specialized cardiothoracic surgery center, where both the surgical and postoperative care processes adhere to the best practices for minimizing recovery time and enhancing patient outcomes. The study was approved by the institutional ethics committee, and all participants provided written informed consent before enrollment. It was conducted in strict adherence to the ethical principles outlined in the Declaration of Helsinki, ensuring that the rights and well-being of all participants were safeguarded throughout the study. The trial was registered at ClinicalTrials.gov (Identifier: NCT05884164) to ensure transparency and adherence to clinical research standards.

Eighty adult patients aged over 18 years, with American Society of Anaesthesiologists (ASA) physical status III, who were scheduled for minimally invasive mitral valve replacement (MIMVR) via right mini-thoracotomy, were included in the study. Exclusion criteria consisted of patient refusal, infection at the puncture site, known hypersensitivity to local anaesthetics, hepatic or renal impairment, and any contraindication to regional anaesthesia.

The sample size was powered for superiority on 24-hour postoperative morphine consumption (mg). Based on Duran's et al.[9] study showing 19.2 ± 4.26 mg in the ESPB group versus 16.2 ± 2.64 mg in the PVB group, we estimated a pooled SD = 3.54 mg and an expected clinically meaningful difference (Δ) = 2.3 mg. Using a two-sided $\alpha = 0.05$ and power = 80% ($Z_\beta = 0.84$), the required sample size per group was 38 patients per group To compensate for potential dropouts, 40 patients per group (total N = 80) were enrolled.

Randomization was performed by an independent statistician using a computer-generated random sequence. Group allocations were concealed in sequentially numbered, opaque, tamper-proof envelopes, which were opened immediately before the administration of the block. Participants were randomly assigned to receive either an erector spinae plane block (ESPB) or a paravertebral plane block (PVPB) in a 1:1 ratio.

This was a double-blind study. The blocks were performed by a senior anaesthesiologist who was not involved in intraoperative management or data collection. Patients were anesthetized prior to the block procedure to ensure blinding. Intraoperative anaesthesia and postoperative assessments were carried out by separate anaesthesiologists who were unaware of the group allocation. The ultrasound probe and draping field were covered with opaque sterile materials to conceal the block site from the surgical and ICU teams.

All patients received standardized general anaesthesia in accordance with institutional protocols. Single-lung ventilation was achieved using a double-lumen endotracheal tube, and position was confirmed via fiberoptic bronchoscopy. Following induction, ultrasound-guided fascial plane blocks were performed at the T5 level in the lateral position using a Sonoscape® SSI6000 (China) 6–12 MHz linear probe and a 21G insulated blunt-tip needle, under strict aseptic precautions.

For the erector spinae plane block (ESPB), the probe was placed 3 cm lateral to the midline to identify the erector spinae muscle and transverse process. The needle was inserted in-plane (caudo-cranial) to reach the interfascial plane between the muscle and transverse process. Correct needle positioning was confirmed by hydrodissection with 1 mL saline, followed by the injection of 20 mL of 0.25% bupivacaine.

For the paravertebral plane block (PVPB), the probe was oriented longitudinally in a paramedian position to identify the facet joints and transverse processes. The needle was advanced in-plane towards the costotransverse ligament, and

after confirming correct placement with hydrodissection, 20 mL of 0.25% bupivacaine was injected under direct sonographic visualization.

All patients were monitored for complications such as pneumothorax, hematoma, or local anaesthetic systemic toxicity. Postoperatively, all patients received 1 g of paracetamol intravenously every 6 hours as standard analgesia and were extubated according to the ERAS protocol. Patients were followed until discharge for pain control adequacy, hemodynamic stability, and recovery milestones, including extubation, ambulation, and ICU/hospital discharge.

The primary outcome was the total 24-hour postoperative morphine consumption (mg) after extubation. Secondary outcomes included intraoperative fentanyl use (µg), time to first postoperative morphine request (hours), Visual Analog Scale (VAS) pain scores at rest, time to extubation and ambulation (hours), ICU and hospital length of stay (days), and the incidence of nausea, vomiting, or respiratory depression.

Statistical analysis was performed using IBM SPSS Statistics for Windows (version 28.0). Quantitative variables were assessed for normality using the Kolmogorov-Smirnov test. Normally distributed data were presented as mean ± standard deviation (SD) and range (minimum–maximum). Between-group comparisons were performed using the independent samples t-test. Categorical variables were analyzed using the Chi-square test or Fisher's exact test, as appropriate. Time-to-event data, such as time to first postoperative morphine request, were compared between groups using the log-rank test. All statistical tests were two-tailed, and a p-value of ≤ 0.05 was considered statistically significant. Results were interpreted based on the predefined primary and secondary outcomes.

3. Results

Between January 2023 and December 2024, a total of 101 patients scheduled for minimally invasive mitral valve replacement were assessed for eligibility. Of these, 21 patients were excluded: 12 did not meet the inclusion criteria, 6 declined participations, and 3 were excluded for logistical reasons. Eighty patients were ultimately randomized in a 1:1 ratio to receive either an erector spinae plane block (ESPB) or a thoracic paravertebral plane block (PVPB). All randomized patients completed the study and were included in the final analysis (**Figure 1**).

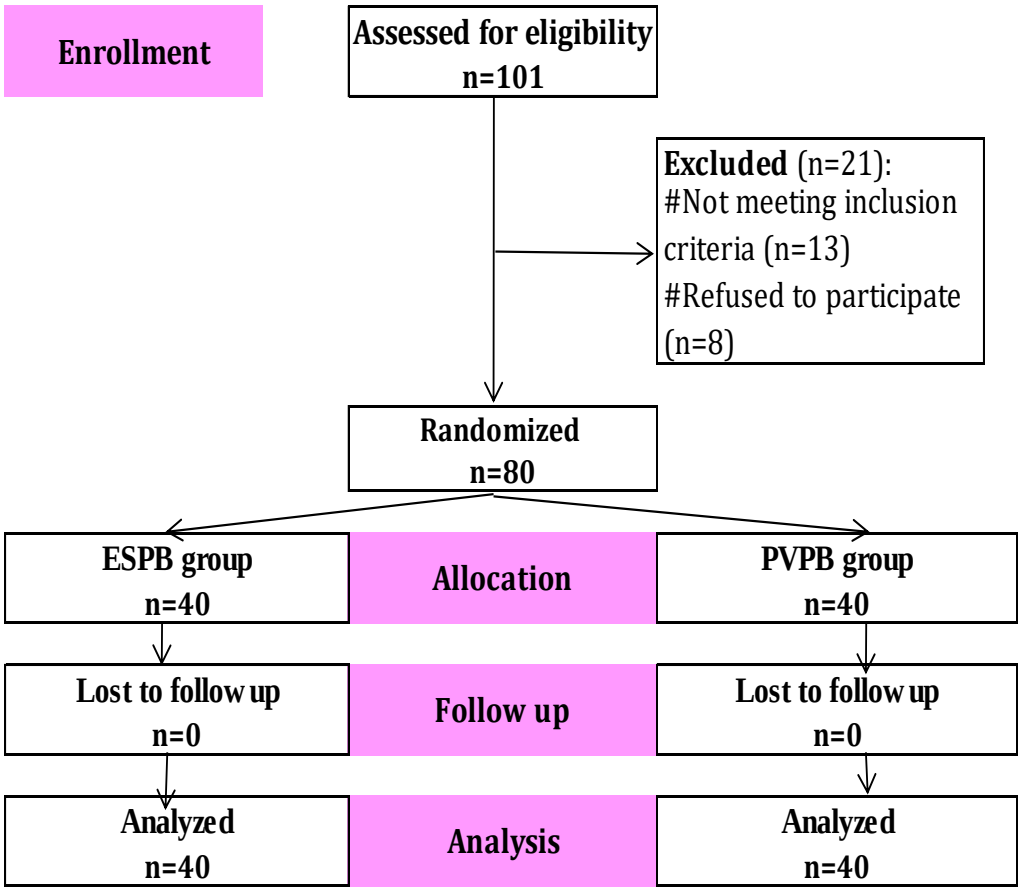

Figure 1: Consort flow chart of the studied cases

The two groups were comparable in baseline demographic and intraoperative variables, including age, sex, body mass index (BMI), and duration of surgery (**Table 1**). No significant differences were observed between the groups in baseline hemodynamic or oxygenation parameters, confirming effective randomization and balanced allocation.

Baseline heart rate, systolic blood pressure, and diastolic blood pressure were similar across the groups. However, during thoracotomy and at postoperative hours 4, 8, 12, and 16, the ESPB group demonstrated significantly lower mean heart rate and blood pressure compared to the PVPB group (**Figure 2**-**Figure 4**). All hemodynamic fluctuations were transient, clinically insignificant, and required no additional pharmacologic intervention.

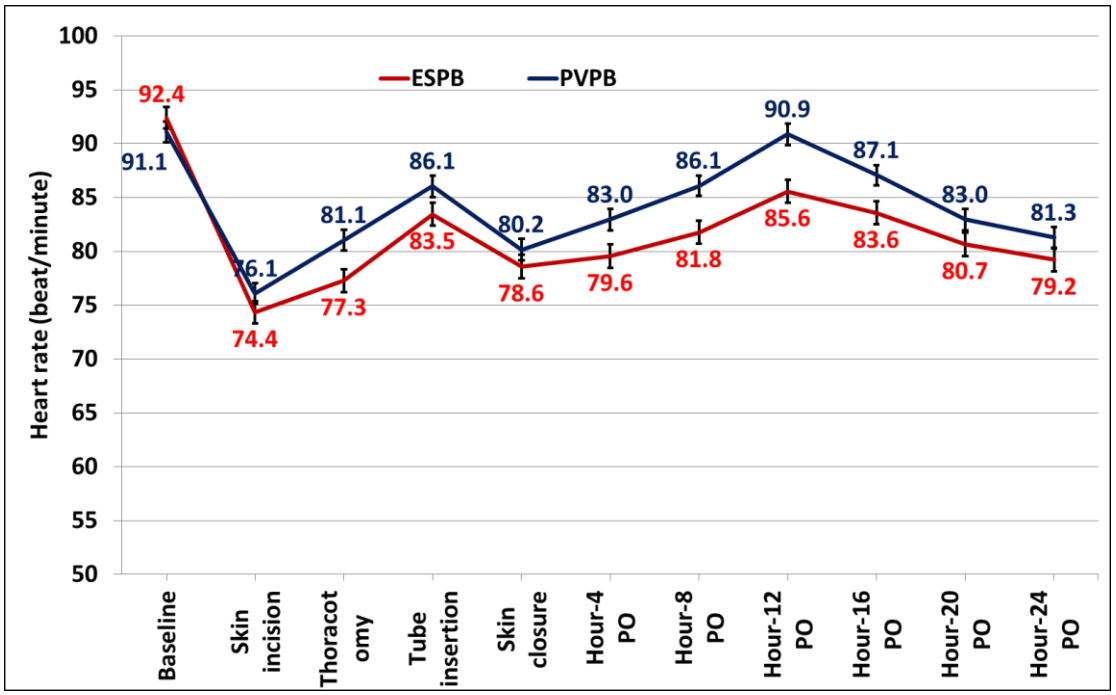

Figure 2: Heart rate between the studied groups

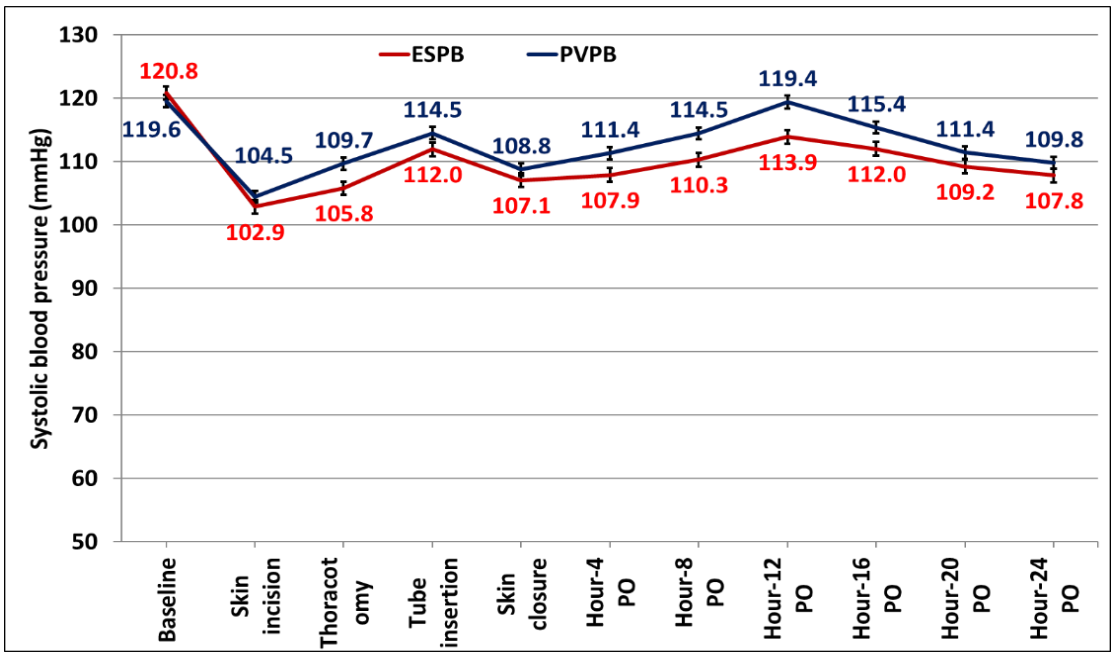

Figure 3: Systolic blood pressure between the studied groups

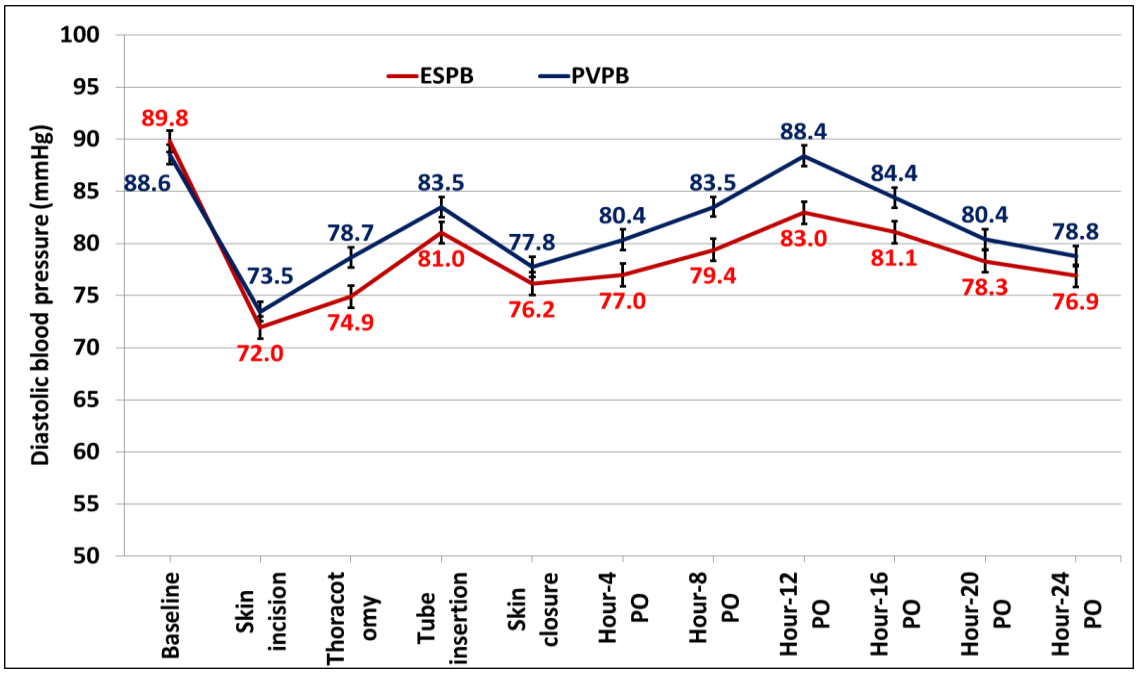

Figure 4: Diastolic blood pressure between the studied groups

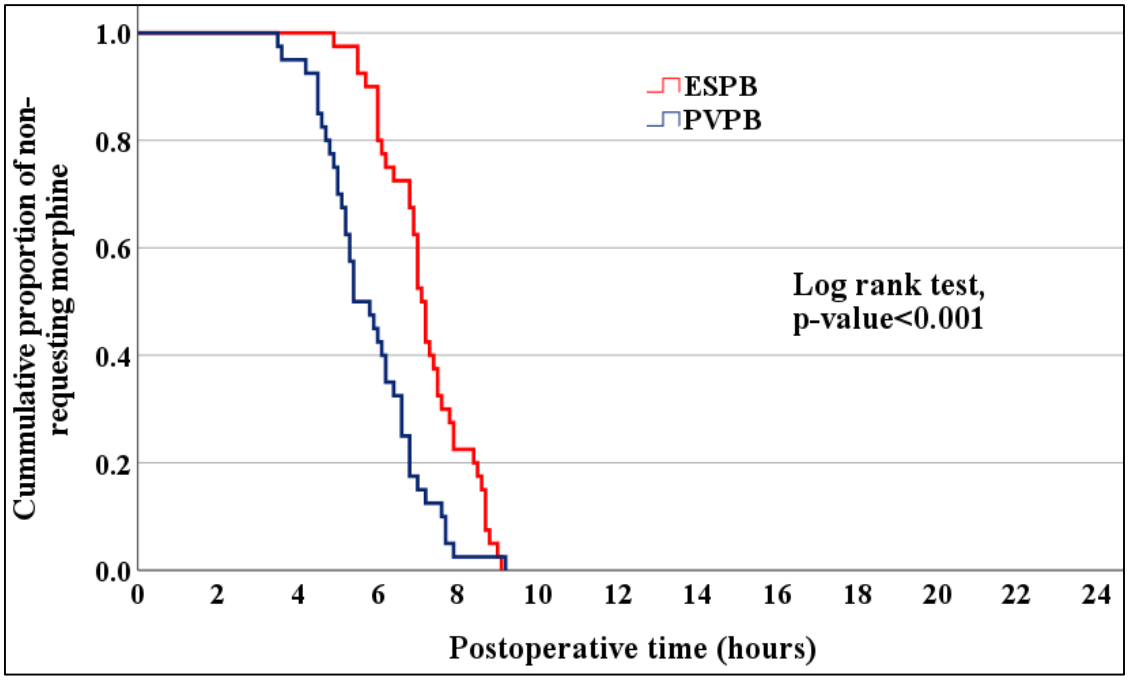

Figure 5: Kaplan-Meier curve for rate of first PO morphine request between the studied groups

The total 24-hour postoperative morphine consumption, which was the primary endpoint of the study, was significantly lower in the ESPB group compared to the PVPB group (**Table 2**). Additionally, the time to the first postoperative morphine request was significantly longer in the ESPB group, indicating a prolonged analgesic duration. The Kaplan–Meier survival analysis of time to first morphine demand showed a significant difference between groups ($\chi^2 = 11.2$, $p < 0.001$) (**Figure 5**).

Total intraoperative fentanyl consumption was significantly lower in the ESPB group, indicating superior intraoperative nociceptive control (**Table 2**). Postoperatively, patients who received ESPB reported consistently lower Visual Analog Scale (VAS) pain scores, with differences reaching statistical significance between the 4th and 18th postoperative hours (**Figure 6**). Oxygen saturation (SpO_2) remained stable and did not differ significantly between groups at any measurement point. Recovery milestones were achieved faster in the ESPB group, with significantly shorter times to extubation and ambulation (**Table 3**). However, ICU discharge time and total hospital stay were similar between the two groups, suggesting comparable overall postoperative recovery trajectories.

No adverse events, including nausea, vomiting, respiratory depression, hematoma, pneumothorax, or local anaesthetic systemic toxicity (LAST), were observed in either group. All blocks were performed under ultrasound guidance and were free of procedural complications. There were no interim analyses or protocol deviations. All patients were analyzed in their assigned groups according to the intention-to-treat principle.

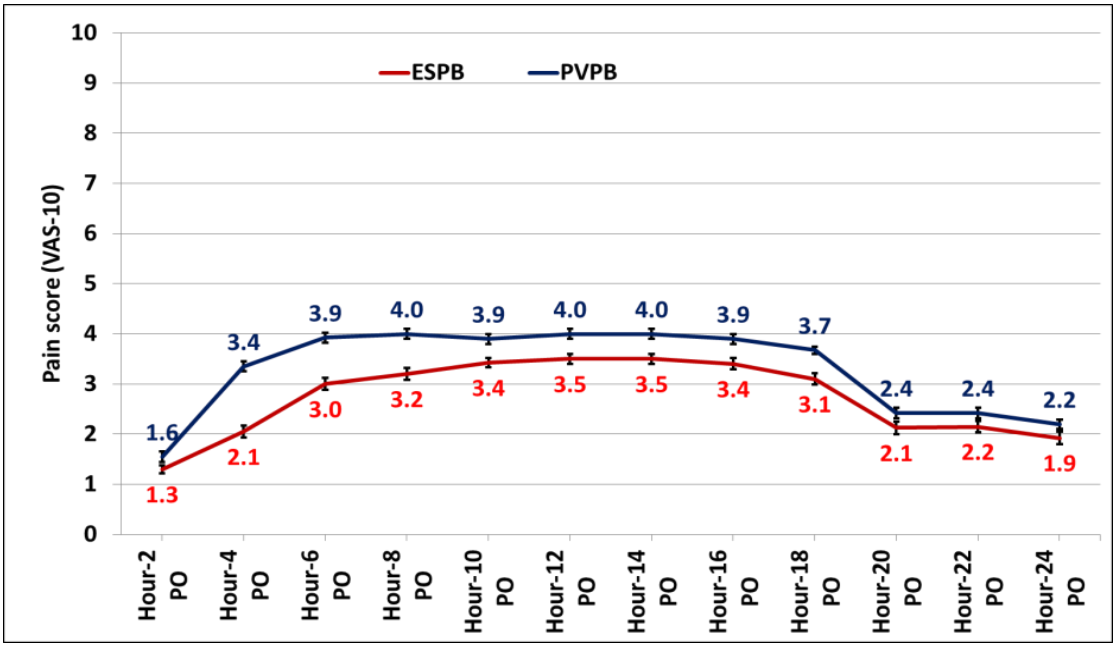

Figure 6: Pain score between the studied groups

Table 1: Baseline characteristics between the studied groups

Variables		ESPB (Total=40)	PVPB (Total=40)	p-value
Age (years)	Mean±SD	38.8±11.3	37.6±10.1	0.618 (Independent t-test)
	Range	19.0–61.0	18.0–62.0	
Sex (n, %)	Male	17 (42.5%)	19 (47.5%)	0.653 (Chi square test)
	Female	23 (57.5%)	21 (52.5%)	
BMI (Body mass index) **(kg/m^2)**	Mean±SD	28.8±2.6	28.4±2.9	0.529 (Independent t-test)
	Range	23.8–35.3	22.6–35.0	
Operation duration (minutes)	Mean±SD	298.1±31.1	303.3±26.6	0.422 (Independent t-test)
	Range	251.0–346.0	247.0–351.0	

Table 2: Analgesics requirements between the studied groups

Variables	Measures	ESPB (Total=40)	PVPB (Total=40)	p-value (Independent t-test)	Relative effect Mean±SE 95% CI
Total IO fentanyl (µg)	Mean±SD	263.8±17.3	303.6±20.2	<0.001*	-39.5±4.2
	Range	230.0–320.0	250.0–350.0		-47.9–-31.1
Total 24-hour morphine (mg)	Mean±SD	11.9±1.3	14.5±1.2	<0.001*	-2.7±0.3
	Range	9.0–15.0	12.0–17.0		-3.2–-2.1
Time to first PO morphine request (hour)	Mean±SD	7.2±1.1	5.8±1.3	<0.001*	1.4±0.3
	Range	4.9–9.1	3.5–9.2		0.8–1.9

IO: Intraoperative. PO: Postoperative. SE: Standard error. CI: Confidence interval. Relative effect: Effect in ESPB group relative to that in PVPB group

Table 3: Times to extubation, ambulation, ICU discharge, and hospital discharge between the studied groups

Variables	Measures	ESPB (Total=40)	PVPB (Total=40)	p-value (Independent t-test)	Relative effect Mean±SE 95% CI
Extubation (hours)	Mean±SD	3.6±0.9	5.4±0.8	**<0.001***	-1.8±0.2
	Range	1.9–6.0	3.4–7.4		-2.2–-1.4
Ambulation (hours)	Mean±SD	7.4±1.0	9.1±1.0	**<0.001***	-1.7±0.2
	Range	5.3–9.8	6.7–10.8		-2.1–-1.2
ICU discharge (days)	Mean±SD	2.3±0.5	2.5±0.5	0.175	-0.2±0.1
	Range	2.0–3.0	2.0–3.0		-0.4–0.1
Hospital discharge (days)	Mean±SD	4.9±0.8	5.1±0.8	0.323	-0.2±0.2
	Range	4.0–6.0	4.0–6.0		-0.5–0.2

SE: Standard error. CI: Confidence interval. Relative effect: Effect in the ESPB group relative to that in the PVPB group

4. Discussion

Enhanced Recovery After Cardiac Surgery (ERACS) protocols aim to standardize perioperative interventions to optimize patient outcomes, particularly by minimizing complications and accelerating recovery. One of the most crucial aspects of these protocols is effective pain management, which plays a pivotal role in achieving faster recovery and an earlier return to normal activity. Inadequate analgesia following cardiac surgery can be debilitating and lead to a variety of unfavorable outcomes, including atelectasis, pneumonia, prolonged hospitalization, decreased quality of life, and the development of chronic postoperative pain syndrome.[10] In this study, both groups of patients who received either the ESPB or PVPB demonstrated markedly lower postoperative morphine doses than typically required in patients who do not receive fascial plane blocks, highlighting the effectiveness of these techniques in reducing opioid consumption. Additionally, both groups achieved Visual Analog Scale (VAS) scores of ≤ 4, indicating effective analgesia that facilitated a fast-track recovery process. This was reflected in shorter ventilator durations, reduced ICU stays, and the successful achievement of ERAS objectives.

Fascial plane blocks, including ESPB and PVPB, have gained widespread acceptance as effective and safe analgesic techniques in cardiac surgery. These blocks are integral components of ERAS protocols, providing satisfactory pain control with ultrasound guidance to ensure procedural safety. Despite their increasing use, the literature on the efficacy of the Erector Spinae Plane Block (ESPB) in cardiac surgery is still limited, with most of the available evidence coming from case reports and small series involving non-cardiac surgeries. However, recent studies and guidelines have begun to establish the role of these techniques in improving postoperative analgesia, particularly in thoracic surgery.

Fascial plane blocks have gained widespread acceptance as effective and safe analgesic techniques in cardiac surgery. They constitute an integral component of ERAS protocols, offering satisfactory pain control with ultrasound guidance ensuring procedural safety. Despite this, there remains limited literature on the efficacy of the Erector Spinae Plane Block (ESPB), with most prior evidence derived from case reports and small series in non-cardiac surgeries.

The Thoracic Paravertebral Plane Block (PVPB) has been endorsed in recent ERAS guidelines as a reliable alternative to thoracic epidural anaesthesia. It demonstrates comparable analgesic efficacy with a lower incidence of complications. Simultaneously, the ESPB has gained increasing popularity due to its versatility, safety profile, and efficacy in various surgical contexts. Several trials have sought to compare PVPB and ESPB, particularly in thoracic surgery settings. A 2023 meta-analysis by Capuano et al. which included 10 randomized trials with 624 patients, compared these two blocks.[11] The results indicated that PVPB provided improved pain control at 12 hours postoperatively and reduced opioid use at 48 hours. In contrast, ESPB demonstrated a slightly lower incidence of block-related complications, suggesting that ESPB may be preferable in patients undergoing Video-Assisted Thoracoscopic Surgery (VATS) or in those with coagulation disorders.

Our study's findings are consistent with the meta-analysis by Das et al., which also highlighted ESPB as the most effective regional technique for reducing postoperative opioid consumption.[12] Although their study focused on patients undergoing open cardiac procedures, our research, which involved minimally invasive cardiac surgery, found similar results. This suggests that ESPB is effective across different surgical approaches, offering significant opioid-sparing benefits and potentially improving recovery outcomes.

The technique of ESPB was first described by Forero et al. for the management of chronic thoracic neuropathic pain.[7] Forero reported a sensory block extending from T1 to T12 following the injection of 25 mL of local anaesthetic at the T5 level. In our study, both groups—ESPB and PVPB—achieved adequate analgesia with a single 20 mL injection, maintaining VAS scores ≤ 4 throughout the first 24 hours postoperatively. These results further support the

effectiveness of ESPB in providing reliable pain relief after minimally invasive cardiac surgery.

In another randomized trial comparing PVPB, ESPB, and the serratus anterior plane block (SAPB) for thoracotomy, the single-shot ESPB provided superior analgesic efficacy and lower opioid consumption during the first 24 hours compared to the other techniques.[12] This further strengthens the argument for using ESPB as a primary regional anaesthesia technique in thoracic surgeries, including minimally invasive cardiac procedures.

Although the implementation of ESPB in cardiac surgery is relatively recent, several studies have demonstrated its successful application in both adult and pediatric cardiac surgeries.[13,14] In comparative studies of continuous ESPB versus thoracic epidural anaesthesia in cardiac surgery via median sternotomy, ESPB not only provided superior analgesia but also proved easier to perform and safer in some cases.[15] Additionally, a randomized controlled trial evaluating bilateral single-shot ESPB versus intravenous acetaminophen and tramadol in cardiac surgery found that ESPB significantly reduced pain scores and prolonged postoperative analgesia duration.[16] Another investigation demonstrated that continuous ESPB reduced intraoperative sufentanil and postoperative morphine requirements compared with controls.[17]

Similarly, bilateral PVPB has been shown to provide excellent postoperative analgesia, hemodynamic stability, and earlier extubation in conventional cardiac surgery.[18,19] In fully heparinized patients undergoing aortic valve replacement or coronary artery bypass grafting (CABG), preoperative bilateral PVPB reduced both intraoperative and postoperative fentanyl consumption, facilitating early extubation.[20]

One of the major concerns with regional blocks in cardiac surgery is safety in anticoagulated or coagulopathic patients, as both preoperative antiplatelet therapy and intraoperative heparinization increase the risk of bleeding. Complications such as epidural hematomas have been reported with thoracic epidural anaesthesia.[21,22] However, several studies have demonstrated that thoracic paravertebral blocks and ESPB can be performed safely in anticoagulated patients without complications. A retrospective review of 138 cardiac surgery patients receiving paravertebral block catheters found no evidence of epidural, paravertebral, or spinal hematomas despite concurrent anticoagulation.[23] Similarly, a case series of five coagulopathic patients who underwent ESPB reported no bleeding complications.[24] Another study involving anticoagulated patients undergoing minimally invasive mitral valve surgery demonstrated that both continuous ESPB and serratus anterior plane blocks were safely performed without any hematoma or bleeding events.[25]

In our study, no hematoma or bleeding complications were observed intraoperatively or postoperatively, reinforcing the safety of both ESPB and PVPB for minimally invasive cardiac procedures. Despite this, the technical simplicity, clear sonographic anatomy, and greater distance from critical neurovascular structures suggest that ESPB may offer a superior safety profile when compared to PVPB.

Contrary to our findings, a randomized trial reported that combining PVPB with ESPB provided superior analgesia compared to ESPB alone, although it showed similar efficacy to PVPB when performed postoperatively in VATS patients.[26] This may be because combining PVPB and ESPB offers a broader coverage of pain pathways, with PVPB providing targeted nerve blockade and ESPB offering a wider area of analgesia. However, in minimally invasive procedures like VATS, the pain intensity may not require the additional benefit from combining both blocks, making the efficacy of the combination similar to PVPB alone.

Additionally, another study comparing PVPB, ESPB, and intercostal nerve blocks after thoracoscopic surgery found that while all three techniques provided satisfactory analgesia, PVPB achieved the greatest pain reduction and lowest morphine consumption, positioning it as the preferred regional technique.[27] This suggests that PVPB, with its focused blockade of intercostal nerves, may offer superior pain control in thoracoscopic procedures, where targeted analgesia is critical for managing pain effectively and minimizing opioid use.

This study also had some limitations. First, it was conducted at a single tertiary cardiac center, which may limit the generalizability of the results to other institutions with different perioperative practices or patient populations. Second, the study population was restricted to patients undergoing minimally invasive mitral valve replacement, so the findings may not be directly applicable to other cardiac procedures such as coronary artery bypass grafting or valve surgery via median sternotomy. Third, although the sample size was sufficient to detect significant differences in postoperative opioid consumption, larger multicenter studies are needed to confirm these results and to evaluate long-term outcomes, including the development of chronic pain and functional recovery. Lastly, the use of a single-shot technique in both groups limits the duration of analgesia; continuous catheter-based approaches may offer more prolonged benefits and should be explored in future research to assess their impact on sustained pain relief and recovery.

5. Conclusion

Ultrasound-guided erector spinae plane block (ESPB) provides superior postoperative analgesia, greater opioid-sparing efficacy, and faster recovery compared with thoracic paravertebral plane block (PVPB) in patients undergoing minimally invasive mitral valve replacement within an ERAS protocol. Both blocks are safe and free of complications.

Despite the need for further studies, our findings support the increasing use of ESPB in cardiac surgery, particularly in patients with specific needs such as those undergoing minimally invasive procedures or those at higher risk for complications associated with traditional regional anaesthesia techniques.

6. Source of Funding

None.

7. Conflict of Interest

None.

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