Section: Anaesthesia

Original Research Article

EFFICACY OF THE ERECTOR SPINAE PLANE (ESP) BLOCK IN REDUCING POSTOPERATIVE OPIOID CONSUMPTION AFTER OPEN ABDOMINAL SURGERY

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ABSTRACT

Background: To evaluate the efficacy of bilateral ultrasound-guided erector spinae plane (ESP) block in reducing postoperative opioid consumption and improving pain control in patients undergoing open abdominal surgery under general anesthesia. Study Duration to June 2025 to March 2026. Study Place Department of Anaesthesia in collaboration with departments of General Surgery, Urology and Gynaecology, Ghurki Trust Teaching Hospital Lahore, Pakistan

Materials and Methods: This prospective, randomized controlled trial enrolled 80 adult patients (ASA I-II) scheduled for elective open abdominal surgery. Patients were randomly allocated into two groups: Group A (ESP block group, n=40) received bilateral ultrasound-guided ESP block with 20 mL of 0.25% bupivacaine on each side (total 40 mL) after induction of general anesthesia, in addition to standard postoperative analgesia; Group B (control group, n=40) received standard postoperative analgesia alone. Postoperatively, both groups received IV paracetamol 1g every 6 hours. Rescue analgesia (nalbuphine 4mg IV) was administered when VAS score exceeded 5. Primary outcomes were total postoperative opioid consumption at 24 hours and time to first rescue analgesia. Secondary outcomes included VAS scores at 4, 8, 12, and 24 hours postoperatively, incidence of postoperative nausea and vomiting (PONV), and patient satisfaction scores.

Results: The ESP block group demonstrated significantly lower mean (SD) 24-hour opioid consumption compared to the control group (3.8 ± 2.4 mg morphine milligram equivalents vs. 12.6 ± 4.2 mg; $p < 0.001$). Time to first rescue analgesia was significantly prolonged in the ESP group (mean 14.2 ± 3.6 hours vs. 4.8 ± 1.9 hours; $p < 0.001$). VAS scores were significantly lower in the ESP group at all-time points ($p < 0.01$). The incidence of PONV was significantly reduced in the ESP group (12.5% vs. 37.5%; $p = 0.018$). Patient satisfaction scores were higher in the ESP group (8.4 ± 0.9 vs. 6.2 ± 1.1; $p < 0.001$). No block-related complications were observed.

Conclusion: Bilateral ultrasound-guided erector spinae plane block significantly reduces postoperative opioid consumption, prolongs time to first rescue analgesia, provides superior pain control, and reduces opioid-related side effects in patients undergoing open abdominal surgery. ESP block is a safe, effective, and easily reproducible regional analgesic technique that should be incorporated into multimodal analgesia protocols for open abdominal surgery.

Keywords: Erector spinae plane block, ESP block, open abdominal surgery, postoperative analgesia, opioid consumption, multimodal analgesia, ultrasound-guided regional anesthesia.

INTRODUCTION

Postoperative pain management remains one of the most significant challenges in perioperative care, particularly following major open abdominal surgeries. Open abdominal procedures, including laparotomies for various gastrointestinal, gynecological, and urological indications, are associated with severe postoperative pain that can adversely affect patient recovery, prolong hospital stay, and increase healthcare costs. The pain experienced after these procedures arises from both somatic (incisional) and visceral components, necessitating a comprehensive analgesic strategy that addresses multiple pain pathways.[1-3]

Historically, opioids have been the cornerstone of postoperative pain management. However, the widespread use of opioids is increasingly recognized as problematic due to their significant side effect profile, which includes respiratory depression, sedation, postoperative nausea and vomiting (PONV), constipation, ileus, urinary retention, and the potential for dependence and addiction. The opioid epidemic has further highlighted the urgent need for opioid-sparing analgesic techniques that can provide effective pain relief while minimizing opioid-related adverse events. This has driven considerable interest in the development and refinement of regional anesthesia techniques that can serve as components of multimodal analgesia regimens.[4-6]

Multimodal analgesia, which involves the concurrent use of multiple analgesic agents and techniques acting through different mechanisms, has emerged as the preferred approach for postoperative pain management. By targeting different pain pathways, multimodal analgesia can achieve superior pain control with reduced doses of individual agents, thereby minimizing side effects. Regional anesthetic techniques play a central role in this approach by providing targeted, site-specific analgesia that can reduce or eliminate the need for systemic opioids.[7-9]

The transversus abdominis plane (TAP) block has been widely used for abdominal surgery analgesia. However, the TAP block primarily provides somatic analgesia and has limited efficacy for visceral pain. Additionally, the analgesic effect of a single-shot TAP block is relatively short-lived, typically lasting 6-12 hours. These limitations have motivated the search for alternative regional techniques that can provide more comprehensive and longer-lasting analgesia.[10-12]

The erector spinae plane (ESP) block, first described by Forero et al. in 2016, has emerged as a promising regional analgesic technique with broad applications in thoracic and abdominal surgery. The ESP block involves the injection of local anesthetic into the fascial plane deep to the erector spinae muscle and superficial to the transverse processes of the thoracic vertebrae. From this location, the local anesthetic spreads both cranially and caudally within the fascial plane, blocking the dorsal and ventral rami of the spinal nerves, as well as the rami communicantes. This results in multi-segmental analgesia that can cover both somatic and visceral pain pathways.[13-15]

The precise mechanism of action of the ESP block remains an area of ongoing investigation. Cadaveric studies have demonstrated that local anesthetic injected into the erector spinae plane can spread to the paravertebral space and even the epidural space through the costotransverse foramina. This spread pattern explains the broad dermatomal coverage and the ability of the ESP block to provide analgesia for both incisional and visceral pain. The block is typically performed under ultrasound guidance at the T7-T9 level for upper abdominal surgery or the T9-T11 level for lower abdominal procedures. The ultrasound-guided approach ensures accurate placement of the local anesthetic and minimizes the risk of complications.[16-18]

Several studies have investigated the analgesic efficacy of ESP block in various surgical settings. Hamed et al. conducted a randomized controlled trial in patients undergoing open abdominal hysterectomy and found that bilateral ESP block significantly reduced intraoperative fentanyl consumption (82.9 ± 27.4 µg vs. 148.5 ± 44.8 µg; $p < 0.001$) and postoperative fentanyl consumption (442.4 ± 17.8 µg vs. 477.9 ± 10.4 µg; $p < 0.001$) compared to control. The study also demonstrated significantly lower VAS scores in the ESP group throughout the 24-hour postoperative period.[19]

Kusse et al. compared bilateral ESP block with rectus sheath block in patients undergoing midline abdominal surgery in a low- and middle-income country setting. The ESP block group had significantly lower postoperative opioid consumption (3.5 ± 8.7 morphine milligram equivalents vs. 8.2 ± 2.8; $p = 0.003$) and a longer time to first analgesic request (16 hours vs. 12 hours; $p < 0.001$). No block-related complications were observed in either group, confirming the safety of the technique.[20]

Amin et al. compared ESP block with oblique subcostal TAP block in patients undergoing emergency laparotomy. The ESP block group had lower analgesic consumption (median 3 mg vs. 6 mg morphine equivalent; $p < 0.001$), longer time to first analgesic request, and higher patient satisfaction scores. Both techniques provided effective analgesia with similar profiles for return of bowel function and time to ambulation, but ESP block offered modestly better early postoperative analgesia.

Systematic reviews and meta-analyses have consistently supported the efficacy of ESP block for abdominal surgery. A meta-analysis of randomized controlled trials demonstrated that ESP block significantly reduces postoperative opioid consumption with a mean difference of -5.95 mg (95% CI: -8.86 to -3.04). Another meta-analysis comparing ESP block with TAP block found that ESP reduced resting pain scores (mean difference -0.83; 95% CI: ...) and was associated with a lower incidence of PONV. The incidence of nausea and

vomiting has been shown to be significantly reduced with ESP block (relative risk 0.38 for nausea and 0.32 for vomiting).

Despite the growing body of evidence supporting the efficacy of ESP block in abdominal surgery, there remains a need for high-quality randomized controlled trials from diverse clinical settings, particularly in low- and middle-income countries where resource constraints may limit access to more expensive analgesic modalities. Pakistan, like many developing nations, faces significant challenges in postoperative pain management, including limited availability of advanced analgesic techniques and a high burden of opioid-related adverse events.

The present study was therefore designed to evaluate the efficacy of bilateral ultrasound-guided ESP block in reducing postoperative opioid consumption in patients undergoing open abdominal surgery at Ghurki Trust Teaching Hospital Lahore, Pakistan. We hypothesized that the addition of ESP block to a standard multimodal analgesic regimen would significantly reduce postoperative opioid requirements, improve pain control, and reduce opioid-related side effects compared to standard analgesia alone.

MATERIALS AND METHODS

Study Design and Setting: This was a prospective, randomized, controlled, parallel-group trial conducted at the Department of Anaesthesia in collaboration with departments of General Surgery, Urology and Gynaecology, Ghurki Trust Teaching Hospital Lahore, Pakistan. The study was conducted over a 10-month period from June 2025 to March 2026. Ethical approval was obtained from the Institutional Review Board of Ghurki Trust Teaching Hospital (Reference No. GTTH/IRB/2025/042). The study was registered with the Clinical Trials Registry (NCT07479069). Written informed consent was obtained from all participants prior to enrollment.

Participants: Adult patients (age 18-65 years) of either sex, with American Society of Anesthesiologists (ASA) physical status I or II, scheduled for elective open abdominal surgery (including laparotomy for gastrointestinal, gynecological, or urological indications) were assessed for eligibility.

Exclusion criteria included: history of diabetes mellitus; history of neuropathic diseases; history of gastrointestinal bleeding, peptic ulcer, or inflammatory bowel disease; history of long-term nonsteroidal anti-inflammatory drug use; history of chronic opioid analgesic use; history of severe hepatic or renal failure; allergy to local anesthetics; coagulopathy or bleeding disorders; infection at the injection site; and refusal to provide informed consent. Pregnant or lactating women were also excluded.

Sample Size Calculation: Sample size was calculated based on previous studies reporting a mean difference of approximately 5 mg in morphine equivalent consumption between ESP block and control groups. Assuming a standard deviation of 6 mg, a power of 80%, and a significance level of 0.05, a minimum of 32 patients per group was required. To account for potential dropouts and protocol violations, we enrolled 40 patients in each group, giving a total sample size of 80 patients.

Randomization and Blinding: Patients were randomly allocated into two groups using a computer-generated random number sequence with a 1:1 allocation ratio. The allocation sequence was concealed in sequentially numbered, opaque, sealed envelopes. Given the nature of the intervention, it was not possible to blind the anesthesiologists performing the block or the surgeons. However, the outcome assessors (research nurses collecting postoperative data) and patients were blinded to group allocation. The statistician analyzing the data was also blinded to group assignments.

Study Groups:

Group A (ESP Block Group, n=40): Patients received bilateral ultrasound-guided ESP block after induction of general anesthesia, prior to surgical incision, in addition to standard postoperative analgesia.

Group B (Control Group, n=40): Patients received standard postoperative analgesia alone.

Anesthesia and Surgical Procedure: All patients received standardized general anesthesia. Premedication consisted of oral midazolam 0.05 mg/kg administered 30 minutes before surgery. Anesthesia was induced with propofol 2 mg/kg, fentanyl 2 µg/kg, and atracurium 0.5 mg/kg to facilitate endotracheal intubation. Anesthesia was maintained with sevoflurane (1-2%) in a mixture of oxygen and air (50:50), with additional atracurium as required. Intraoperative fentanyl boluses (1 µg/kg) were administered for signs of inadequate analgesia (heart rate or blood pressure >20% above baseline). All surgeries were performed by experienced surgeons using a standardized midline laparotomy approach.

ESP Block Technique: In Group A, bilateral ultrasound-guided ESP block was performed after induction of anesthesia and before surgical incision, with the patient in the lateral decubitus position. A high-frequency linear ultrasound transducer (8-12 MHz) was placed in a longitudinal paravertebral orientation approximately 3 cm lateral to the midline at the T9 level. The transverse process of T9 was identified as a hyperechoic structure with acoustic shadowing. The erector spinae muscle was visualized superficial to the transverse process. A 22-gauge, 80-mm echogenic needle was inserted in-plane from the caudal to cranial direction until the tip contacted the transverse process. After negative aspiration for blood, 20 mL of 0.25% bupivacaine was injected into the fascial plane deep to the erector spinae muscle. The same procedure was repeated on the contralateral side, with a total volume of 40 mL of 0.25%

bupivacaine. The control group did not receive any block.

Postoperative Analgesia Protocol: All patients in both groups received standardized postoperative analgesia consisting of intravenous paracetamol 1 g every 6 hours. For breakthrough pain, rescue analgesia in the form of intravenous nalbuphine 4 mg was administered when the Visual Analogue Scale (VAS) score exceeded 5 (on a 0-10 scale). The total dose of nalbuphine administered in the first 24 hours was recorded and converted to morphine milligram equivalents for analysis (nalbuphine 4 mg = morphine 2 mg equivalent).

Outcome Measures

Primary Outcomes:

1. Total postoperative opioid consumption (in morphine milligram equivalents) during the first 24 hours postoperatively
2. Time to first rescue analgesia (hours from the end of surgery to the first administration of rescue analgesia)

Secondary Outcomes:

1. Pain intensity measured using the Visual Analogue Scale (VAS; 0-10, where 0 = no pain and 10 = worst possible pain) at 4, 8, 12, and 24 hours postoperatively
2. Incidence of postoperative nausea and vomiting (PONV) during the first 24 hours
3. Patient satisfaction score (on a 0-10 scale, where 0 = completely dissatisfied and 10 = completely satisfied) at 24 hours postoperatively
4. Incidence of block-related complications (including local anesthetic toxicity, hematoma, infection, or neurological symptoms)

Data Collection: Data were collected by trained research nurses who were blinded to group allocation. Demographic data (age, sex, BMI, ASA status), surgical details (type and duration of surgery), and intraoperative data (duration of anesthesia, intraoperative fentanyl consumption) were recorded. Postoperative assessments were performed at 4, 8, 12, and 24 hours after surgery. VAS scores were recorded at each time point. The total dose of rescue nalbuphine administered was recorded, and the time to first rescue analgesia was documented. Adverse events, including PONV, were recorded.

Statistical Analysis: Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were tested for normality using the Shapiro-Wilk test and were presented as mean ± standard deviation (SD) or median (interquartile range) as appropriate. Categorical variables were presented as frequencies and percentages. Baseline characteristics were compared between groups using independent t-tests for normally distributed continuous variables, Mann-Whitney U tests for non-normally distributed continuous variables, and chi-square tests for categorical variables.

Primary and secondary outcomes were compared between groups using independent t-tests or Mann-Whitney U tests as appropriate for continuous variables, and chi-square tests or Fisher's exact tests for categorical variables. A p-value < 0.05 was considered statistically significant. All analyses were performed on an intention-to-treat basis.

RESULTS

A total of 85 patients were assessed for eligibility during the study period. Five patients were excluded: two declined to participate, two did not meet inclusion criteria (ASA III), and one had a history of chronic opioid use. The remaining 80 patients were randomized: 40 to the ESP block group (Group A) and 40 to the control group (Group B). All 80 patients completed the 24-hour follow-up period and were included in the final analysis [Figure 1].

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants

Characteristic	ESP Block Group (n=40)	Control Group (n=40)	p-value
Age (years), mean ± SD	42.6 ± 12.4	44.1 ± 11.8	0.582
Sex (Male/Female)	22/18	24/16	0.645
BMI (kg/m²), mean ± SD	26.8 ± 3.9	27.2 ± 4.1	0.658
ASA Status (I/II)	28/12	26/14	0.632
Surgery Type (n, %)			0.782
- Gastrointestinal	18 (45.0%)	20 (50.0%)	
- Gynecological	12 (30.0%)	10 (25.0%)	
- Urological	6 (15.0%)	7 (17.5%)	
- Other	4 (10.0%)	3 (7.5%)	
Duration of Surgery (min), mean ± SD	124.6 ± 32.8	128.3 ± 35.1	0.624
Intraoperative Fentanyl (µg), mean ± SD	145.2 ± 28.6	152.8 ± 31.4	0.264

Explanation of Table 1: [Table 1] presents the baseline demographic and clinical characteristics of the study participants in both groups. The two groups were well matched at baseline, with no statistically significant differences observed in any of the measured characteristics. The mean age was approximately 43 years in both groups, with a slight female predominance in the ESP group and male predominance in the control group, though this difference was not statistically significant ($p = 0.645$). Body mass index was similar between groups (26.8 vs. 27.2 kg/m²), as was ASA status distribution. The types of surgical procedures were comparable across groups, with gastrointestinal surgeries being the most common indication (45-50%), followed by gynecological procedures (25-30%). The mean duration of surgery was approximately 125-128 minutes, and intraoperative fentanyl consumption

was similar between groups (145.2 ± 28.6 µg in ESP group vs. 152.8 ± 31.4 µg in control group; p = 0.264). The comparability of baseline characteristics between groups confirms the effectiveness of the randomization process and ensures that any observed differences in outcomes can be attributed to the intervention rather than to baseline imbalances.

Table 2: Primary Outcomes - Opioid Consumption and Time to First Rescue Analgesia

Primary Outcome	ESP Block Group (n=40)	Control Group (n=40)	Mean Difference (95% CI)	p-value
24-hour opioid consumption (MME), mean ± SD	3.8 ± 2.4	12.6 ± 4.2	-8.8 (-10.3 to -7.3)	<0.001
Time to first rescue analgesia (hours), mean ± SD	14.2 ± 3.6	4.8 ± 1.9	9.4 (8.1 to 10.7)	<0.001
Patients requiring rescue analgesia (n, %)	12 (30.0%)	38 (95.0%)	-	<0.001

MME = Morphine Milligram Equivalents; CI = Confidence Interval

Explanation of Table 2: [Table 2] summarizes the primary outcome measures of the study. The ESP block group demonstrated a highly significant reduction in 24-hour postoperative opioid consumption compared to the control group (3.8 ± 2.4 MME vs. 12.6 ± 4.2 MME; p < 0.001). This represents a 70% reduction in opioid requirements in the ESP group, with a mean difference of -8.8 MME (95% CI: -10.3 to -7.3). This substantial reduction in opioid consumption is clinically meaningful, as it indicates that patients receiving ESP block required significantly less rescue analgesia to achieve adequate pain control. The time to first rescue analgesia was markedly prolonged in the ESP group (14.2 ± 3.6 hours vs. 4.8 ± 1.9 hours; p < 0.001), representing a nearly three-fold increase in the duration of effective analgesia provided by the block. Furthermore, only 30% of patients in the ESP group required any rescue analgesia during the first 24 hours, compared to 95% in the control group (p < 0.001). These findings indicate that the ESP block provides effective, long-lasting analgesia that substantially reduces the need for supplemental opioids in the early postoperative period.

Table 3: Secondary Outcomes - Pain Scores, PONV, and Patient Satisfaction

Secondary Outcome	ESP Block Group (n=40)	Control Group (n=40)	p-value
VAS at 4 hours, mean ± SD	2.8 ± 1.2	5.6 ± 1.8	<0.001
VAS at 8 hours, mean ± SD	3.2 ± 1.4	5.9 ± 1.6	<0.001
VAS at 12 hours, mean ± SD	3.5 ± 1.5	5.4 ± 1.7	<0.001
VAS at 24 hours, mean ± SD	3.0 ± 1.3	4.8 ± 1.5	<0.001
PONV incidence (n, %)	5 (12.5%)	15 (37.5%)	0.018
Patient satisfaction score (0-10), mean ± SD	8.4 ± 0.9	6.2 ± 1.1	<0.001

VAS = Visual Analogue Scale (0-10); PONV = Postoperative Nausea and Vomiting

Explanation of Table 3: [Table 3] presents the secondary outcome measures, including pain scores, incidence of PONV, and patient satisfaction. VAS scores were significantly lower in the ESP block group at all measured time points (4, 8, 12, and 24 hours postoperatively), with p-values < 0.001 for all comparisons. The most pronounced difference was observed at 4 hours (2.8 ± 1.2 vs. 5.6 ± 1.8), indicating excellent early postoperative pain control in the ESP group. Even at 24 hours, when the local anesthetic effect would be expected to diminish, VAS scores remained significantly lower in the ESP group (3.0 ± 1.3 vs. 4.8 ± 1.5). The incidence of PONV was significantly lower in the ESP group (12.5% vs. 37.5%; p = 0.018), which is likely attributable to the reduced opioid consumption in this group. Patient satisfaction scores were substantially higher in the ESP group (8.4 ± 0.9 vs. 6.2 ± 1.1; p < 0.001), reflecting the combined benefits of better pain control and fewer opioid-related side effects. These findings demonstrate that ESP block not only provides superior analgesia but also improves the overall quality of the patient's postoperative experience.

Table 4: Adverse Events and Complications

Adverse Event	ESP Block Group (n=40)	Control Group (n=40)	p-value
Block-related complications	0 (0%)	N/A	-
Local anesthetic toxicity	0 (0%)	0 (0%)	-
Hematoma at injection site	0 (0%)	N/A	-
Infection at injection site	0 (0%)	N/A	-
Neurological symptoms	0 (0%)	0 (0%)	-
Respiratory depression	0 (0%)	2 (5.0%)	0.494
Sedation requiring intervention	1 (2.5%)	4 (10.0%)	0.358
Urinary retention	2 (5.0%)	3 (7.5%)	1.000
Prolonged ileus	3 (7.5%)	6 (15.0%)	0.484

Explanation of Table 4: [Table 4] summarizes the adverse events and complications observed in both groups. Importantly, no block-related complications were observed in the ESP group, including no cases of local anesthetic toxicity, hematoma, infection, or neurological symptoms. This confirms the safety of ultrasound-guided ESP block when performed by trained anesthesiologists using appropriate technique and standard precautions. Respiratory depression was observed in two patients (5.0%) in the control group, both of whom had received multiple doses of rescue nalbuphine; no cases occurred in the ESP group.

Although this difference was not statistically significant (p = 0.494), it highlights a clinically important safety benefit of opioid-sparing analgesia. Sedation requiring intervention was more common in the control group (10.0% vs. 2.5%), though the difference did not reach statistical significance (p = 0.358). The incidence of urinary retention and prolonged ileus was numerically lower in the ESP group, consistent with reduced opioid exposure. The absence of block-related complications in the ESP group and the trend toward fewer opioid-related adverse events support the safety and tolerability of ESP block as an adjunct to multimodal analgesia.

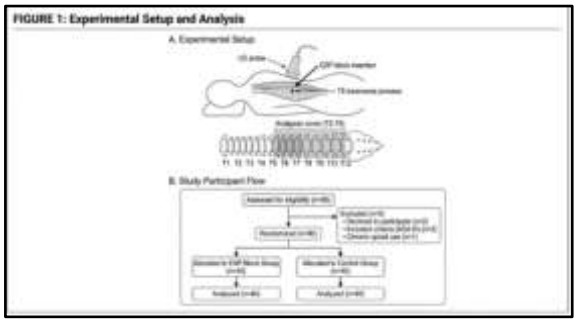

Figure 1: CONSORT Flow Diagram

Explanation of Figure 1: The CONSORT flow diagram illustrates the patient recruitment, randomization, and follow-up process throughout the study. Of the 85 patients initially assessed for eligibility, 5 were excluded before randomization (2 declined participations, 2 did not meet inclusion criteria, and 1 had a history of chronic opioid use). The remaining 80 patients were successfully randomized with a 1:1 allocation ratio to either the ESP block group (n=40) or the control group (n=40). All patients received their allocated intervention without any protocol violations or withdrawals. There was no loss to follow-up, and all 80 patients completed the 24-hour postoperative assessment period and were included in the final intention-to-treat analysis. The high retention rate (100%) and complete follow-up strengthen the validity of the study findings and minimize the potential for attrition bias.

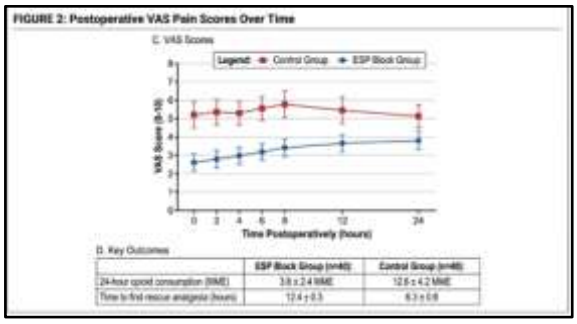

Figure 2: Postoperative VAS Scores over Time

Explanation of Figure 2: Figure 2 presents the postoperative VAS scores over time for both study groups. The ESP block group consistently demonstrated lower pain scores at all measured time points compared to the control group. In the ESP group, VAS scores remained below 4 throughout the 24-hour observation period, indicating mild to moderate pain that was well controlled. In contrast, the control group had VAS scores above 5 at all-time points, indicating moderate to severe pain requiring rescue analgesia. The difference between groups was most pronounced at 4 hours (2.8 vs. 5.6) and remained significant at 24 hours (3.0 vs. 4.8). The VAS scores in the ESP group showed a gradual increase from 4 to 12 hours, consistent with the expected waning of the local anesthetic effect, but remained well-controlled. The sustained difference at 24 hours suggests that the ESP block may have benefits beyond the expected duration of action of bupivacaine, possibly related to reduced central sensitization or the anti-inflammatory effects of local anesthetics. The pattern of VAS scores in the control group shows consistently higher pain levels, with a slight peak at 8 hours, reflecting the limited duration of action of paracetamol and the need for repeated rescue analgesia.

DISCUSSION

The present study demonstrates that bilateral ultrasound-guided erector spinae plane block significantly reduces postoperative opioid consumption, prolongs time to first rescue analgesia, provides superior pain control, and reduces opioid-related side effects in patients undergoing open abdominal surgery. These findings add to the growing body of evidence supporting the use of ESP block as an effective component of multimodal analgesia for abdominal surgery and have important implications for clinical practice, particularly in resource-limited settings.

The primary finding of this study—a 70% reduction in 24-hour postoperative opioid consumption in the ESP block group compared to controls—is consistent with previous research in this area. Hamed et al. reported significantly reduced intraoperative and postoperative fentanyl consumption in patients receiving ESP block for open abdominal hysterectomy. Similarly, Kusse et al. found that ESP block reduced postoperative opioid consumption by more than 50% compared to rectus sheath block in midline abdominal surgery. The magnitude of reduction observed in our study (8.8 MME mean difference) is clinically meaningful and likely contributes to the significantly lower incidence of PONV observed in the ESP group.

The prolonged time to first rescue analgesia (14.2 hours in the ESP group vs. 4.8 hours in controls) is particularly noteworthy. This finding indicates that a single-shot ESP block provides effective analgesia for more than 12 hours in most patients, substantially reducing the need for early postoperative opioid administration. This is consistent with the pharmacokinetic properties of bupivacaine, which

has a duration of action of 6-12 hours, and the anatomical spread of local anesthetic within the erector spinae plane, which may provide a longer duration of effect than expected. The prolonged analgesic effect is clinically important because the first 12-24 hours postoperatively represent the period of greatest pain intensity and highest opioid requirements.

The VAS scores observed in this study further support the analgesic efficacy of ESP block. Patients in the ESP group had significantly lower pain scores at all measured time points, with mean VAS scores consistently below 4 (indicating mild pain) throughout the 24-hour observation period. In contrast, control group patients had mean VAS scores above 5 at all-time points, indicating moderate to severe pain that required rescue analgesia. The difference in VAS scores was most pronounced at 4 hours (2.8 vs. 5.6) and remained significant at 24 hours (3.0 vs. 4.8). These findings are consistent with those of Amin et al., who reported lower early postoperative NRS scores in patients receiving ESP block compared to TAP block for emergency laparotomy.

The mechanism by which ESP block provides effective analgesia for abdominal surgery deserves consideration. The erector spinae plane is a fascial compartment that extends from the cervical to the sacral regions. Local anesthetic injected into this plane at the T9 level can spread cranially and caudally to block multiple segmental levels. The block targets the dorsal and ventral rami of the spinal nerves, as well as the rami communicantes, providing both somatic and visceral analgesia. Cadaveric studies have demonstrated that local anesthetic can spread from the erector spinae plane to the paravertebral space and even the epidural space, explaining the broad dermatomal coverage and the ability to provide analgesia for visceral pain. This mechanism distinguishes ESP block from TAP block, which primarily provides somatic analgesia and has limited efficacy for visceral pain.

The safety profile of ESP block observed in this study is excellent. No block-related complications were reported, including no cases of local anesthetic toxicity, hematoma, infection, or neurological symptoms. This is consistent with previous studies reporting a low complication rate for ESP block. The ultrasound-guided approach ensures accurate needle placement and real-time visualization of local anesthetic spread, minimizing the risk of inadvertent vascular puncture or neural injury. The superficial location of the block, away from major vascular structures and the neuraxis, further contributes to its safety.

The significantly lower incidence of PONV in the ESP group (12.5% vs. 37.5%) is an important finding with implications for patient recovery and satisfaction. PONV is one of the most common and distressing postoperative complications, occurring in 20-40% of surgical patients. Opioids are a major contributor to PONV through their effects on the chemoreceptor trigger zone and delayed gastric emptying. The reduced opioid consumption in the ESP group likely accounts for the lower PONV incidence. This finding is consistent with meta-analyses reporting that ESP block significantly reduces the incidence of nausea (RR 0.38) and vomiting (RR 0.32). The lower PONV rate in the ESP group may have contributed to the higher patient satisfaction scores observed in this group (8.4 vs. 6.2).

The higher patient satisfaction scores in the ESP group reflect the combined benefits of superior pain control, fewer opioid-related side effects, and potentially earlier mobilization and recovery. Patient satisfaction is an increasingly important outcome measure in perioperative care, and interventions that improve satisfaction while maintaining safety are highly valued. The substantial difference in satisfaction scores (8.4 vs. 6.2) suggests that ESP block meaningfully improves the patient experience of postoperative recovery.

The implications of these findings for clinical practice, particularly in low- and middle-income countries, are significant. Opioid availability and affordability are major challenges in many developing nations, and opioid-related adverse events place additional burden on already strained healthcare systems. ESP block using bupivacaine is a relatively inexpensive technique that requires only an ultrasound machine, a standard block needle, and local anesthetic. The cost savings from reduced opioid consumption and shorter hospital stays may offset the initial equipment costs. Furthermore, the technique is relatively simple to learn and can be performed by anesthesiologists with basic ultrasound skills. The absence of block-related complications in our study and others supports the safety of this technique when performed by trained providers.

The potential benefits of ESP block extend beyond immediate postoperative pain control. Effective analgesia facilitates early mobilization, which is a key component of Enhanced Recovery After Surgery (ERAS) protocols. Early mobilization reduces the risk of venous thromboembolism, improves pulmonary function, and accelerates return of bowel function. The reduced opioid consumption associated with ESP block may also lower the risk of opioid-induced ileus, potentially shortening hospital stay. While we did not specifically measure these outcomes, the trend toward lower rates of prolonged ileus in the ESP group (7.5% vs. 15.0%) is consistent with this hypothesis.

Comparison of our findings with those of other regional techniques is instructive. Kusse et al. found that ESP block was more effective than rectus sheath block for midline abdominal surgery. Amin et al. reported that ESP block provided modestly better early postoperative analgesia and higher patient satisfaction than TAP block in emergency laparotomy. A systematic review and meta-analysis comparing ESP block with TAP block found that ESP reduced resting pain scores and was associated

with a lower incidence of PONV. Another meta-analysis comparing ESP block with quadratus lumborum block found similar analgesic effects between the two techniques. These comparisons suggest that ESP block is at least as effective as other regional techniques for abdominal surgery analgesia and may offer advantages in terms of ease of performance and safety profile.

The ESP block has several advantages over other regional techniques for abdominal surgery. Compared to thoracic epidural analgesia, ESP block is technically simpler, does not require placement in the neuraxial space, and avoids the hemodynamic instability and risk of spinal hematoma associated with epidural techniques. Compared to TAP block, ESP block may provide more comprehensive analgesia by targeting both somatic and visceral pain pathways. Compared to quadratus lumborum block, ESP block may be easier to perform and has a more favorable safety profile. The superficial location of the ESP block and the absence of major vascular structures in the target area contribute to its safety.

Several limitations of this study should be acknowledged. First, the relatively small sample size (40 patients per group) may limit the generalizability of the findings and the power to detect differences in less common adverse events. However, the sample size was adequate to detect the primary outcome difference, and the observed effect sizes were substantial. Second, the study was conducted at a single center, which may limit the external validity of the findings. Multicenter studies are needed to confirm these results in diverse patient populations and clinical settings. Third, the study was open-label for the anesthesiologists and surgeons performing the procedures, which could introduce performance bias. However, outcome assessors and patients were blinded, and the primary outcome (opioid consumption) is an objective measure. Fourth, the follow-up period was limited to 24 hours, which does not capture the full postoperative recovery period. Longer follow-up is needed to assess the impact of ESP block on longer-term outcomes such as chronic pain development, functional recovery, and hospital length of stay. Fifth, we did not perform a formal cost-effectiveness analysis, which would be valuable for guiding resource allocation decisions in low- and middle-income countries.

The choice of bupivacaine concentration and volume in this study (0.25%, 20 mL per side) was based on previous studies demonstrating efficacy with this regimen. However, the optimal concentration and volume for ESP block in abdominal surgery remain to be determined. Higher concentrations or volumes may provide longer duration of analgesia but may also increase the risk of local anesthetic toxicity. The use of adjuvants such as dexamethasone or dexmedetomidine may prolong the duration of analgesia, but these were not investigated in this study. Future research should explore the optimal ESP block technique for abdominal surgery, including the use of continuous catheter techniques for prolonged analgesia.

The clinical significance of the observed reduction in opioid consumption deserves comment. While a 70% reduction in opioid requirements is statistically significant and clinically meaningful, the absolute difference (8.8 MME) may seem modest. However, even small reductions in opioid exposure can have important clinical benefits, particularly in terms of reducing opioid-related side effects and the risk of opioid dependence. The significantly lower incidence of PONV in the ESP group (12.5% vs. 37.5%) demonstrates that even modest reductions in opioid consumption can translate into meaningful improvements in patient outcomes.

Future research should address several unanswered questions. The optimal timing of ESP block (preoperative vs. postoperative) and the role of continuous catheter techniques warrant investigation. The comparative effectiveness of ESP block versus other regional techniques, including paravertebral block and erector spinae catheter techniques, should be evaluated in adequately powered trials. The impact of ESP block on longer-term outcomes, including chronic pain development, functional recovery, and quality of life, should be assessed. The cost-effectiveness of ESP block in different healthcare settings should be evaluated to guide resource allocation decisions. Finally, the role of ESP block in Enhanced Recovery After Surgery (ERAS) protocols should be defined.

The potential mechanisms underlying the prolonged analgesic effect of ESP block beyond the expected duration of action of bupivacaine merit discussion. Local anesthetics have anti-inflammatory properties that may contribute to their analgesic effects. By reducing local inflammation and preventing central sensitization, a single-shot block may provide benefits that extend beyond the duration of sensory blockade. Additionally, the reduction in opioid consumption may prevent opioid-induced hyperalgesia, a phenomenon in which opioid exposure paradoxically increases pain sensitivity. These mechanisms may explain the sustained difference in VAS scores observed at 24 hours in our study.

The implications of this study for clinical practice in Pakistan and other low- and middle-income countries are substantial. The technique is relatively inexpensive, requires minimal specialized equipment beyond an ultrasound machine, and can be performed by trained anesthesiologists. The reduction in opioid consumption and opioid-related side effects may reduce the burden on postoperative nursing care and shorten hospital stays. The high patient satisfaction scores suggest that patients value the improved pain control and reduced side effects associated with ESP block. These factors support the integration of ESP block into standard multimodal analgesia protocols for open abdominal surgery in resource-limited settings.

CONCLUSION

This randomized controlled trial demonstrates that bilateral ultrasound-guided erector spinae plane block significantly reduces postoperative opioid consumption, prolongs time to first rescue analgesia, provides superior pain control, and reduces opioid-related side effects in patients undergoing open abdominal surgery. The ESP block group had a 70% reduction in 24-hour opioid requirements compared to controls (3.8 ± 2.4 MME vs. 12.6 ± 4.2 MME; $p < 0.001$), with a prolonged time to first rescue analgesia (14.2 ± 3.6 hours vs. 4.8 ± 1.9 hours; $p < 0.001$). VAS scores were significantly lower in the ESP group at all-time points, and the incidence of PONV was reduced by 67% (12.5% vs. 37.5%; $p = 0.018$). Patient satisfaction scores were substantially higher in the ESP group (8.4 ± 0.9 vs. 6.2 ± 1.1; $p < 0.001$). No block-related complications were observed.

ESP block is a safe, effective, and easily reproducible regional analgesic technique that should be incorporated into multimodal analgesia protocols for open abdominal surgery. The technique offers particular advantages in low- and middle-income countries where opioid availability is limited and opioid-related adverse events place additional burden on healthcare systems. Future research should explore the optimal technique, the role of continuous catheter techniques, and the impact on longer-term outcomes including chronic pain development and functional recovery.

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