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Comparative efficacy of ultrasound-guided erector spinae plane block versus wound infiltration for postoperative analgesia in instrumented lumbar spinal surgeries

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Abstract

Objective This study compared the efficacy of ultrasound-guided erector spinae plane block (ESPB) and wound infiltration (WI) for postoperative analgesia in patients who underwent lumbar spinal surgery with instrumentation.

Methods In this randomized controlled trial, 80 patients were divided into two groups: ESPB ($n=40$) and WI ($n=40$). Postoperative pain intensity was assessed via the visual analog scale (VAS) at multiple time points within 24 h. Additionally, opioid consumption, time to first rescue analgesia, incidence of postoperative nausea and vomiting (PONV), and patient satisfaction were evaluated.

Results Both ESPB and WI provided effective postoperative pain management, with no significant differences in VAS scores. However, the ESPB group demonstrated a significantly longer duration of analgesia, a shorter time to first rescue analgesia, and lower total tramadol consumption (50 ± 60 mg vs. 100 ± 75 mg; $p=0.010$) than did the WI group. Furthermore, a trend toward reduced PONV incidence was observed in the ESPB group, likely due to its opioid-sparing effect.

Conclusion While both ESPB and WI provided effective postoperative pain management, ESPB demonstrated a distinct advantage by offering a longer duration of analgesia and significantly reducing opioid consumption. These findings suggest that ESPB is more effective than WI for postoperative analgesia in lumbar spinal surgeries, providing prolonged pain relief and improving patient outcomes. Further studies are warranted to explore its long-term benefits and cost-effectiveness.

Trial Registration ClinicalTrials.govPRS: NCT06567964 Date: 08/21/2024 Retrospectively registered.

Key Points

1. Study Objective: This study aimed to compare the efficacy of ultrasound-guided erector spinae plane block (ESPB) with that of wound infiltration (WI) for postoperative analgesia in lumbar spinal surgeries involving instrumentation.

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2. Primary outcome: Postoperative pain intensity was measured via the visual analog scale (VAS) at multiple time points. The VAS scores were comparable between ESPB and WI at all assessed time points, indicating no significant differences in pain scores. However, both techniques still played a role in postoperative pain management.

3. Opioid consumption: ESPB was associated with a significant reduction in total tramadol consumption compared with WI, indicating that an opioid-sparing effect that could reduce the risk of opioid-related side effects.

4. Duration of Analgesia: Patients in the ESPB group experienced a longer duration before requiring rescue analgesia, suggesting that ESPB provides more prolonged pain relief than WI does.

5. Side Effects and Patient Satisfaction: The incidence of postoperative nausea and vomiting (PONV) was lower in the ESPB group, potentially due to reduced opioid consumption. These findings suggest that ESPB may increase patient satisfaction and comfort during the postoperative period.

6. Clinical Implications: These findings support the integration of ESPB into multimodal analgesia protocols for lumbar spinal surgeries, given its potential advantages in reducing opioid consumption and providing extended pain relief.

7. Limitations: This study has several limitations. First, although the sample size was calculated based on a power analysis and was sufficient to detect significant differences in the primary outcomes, a larger sample size might provide more robust insights into secondary outcomes or less common side effects. Additionally, the study was conducted at a single center, which may limit the generalizability of the findings. Future multicenter studies are needed to validate these results across diverse patient populations and clinical practices. Lastly, the follow-up period was limited to 24 h, which does not allow for the assessment of long-term outcomes such as chronic pain development or functional recovery.

8. Future research: Further studies are recommended to explore the long-term benefits of ESPB, its cost-effectiveness, and its potential integration into enhanced recovery protocols (ERASs) for surgical patients.

Keywords Erector Spinae Plane Block, Wound Infiltration, Postoperative Analgesia, Lumbar Spinal Surgery, Ultrasound-Guided Anesthesia, Postoperative Pain, Visual Analog Scale (VAS), Enhanced Recovery after Surgery (ERAS)

Introduction

Lumbar spinal surgeries are commonly performed to treat conditions including disc herniation and spinal stenosis [1, 2]. These surgeries, although beneficial in addressing underlying spinal issues, often result in significant postoperative pain. Spinal surgeries, especially those involving instrumentation, result in significant postoperative pain due to the nature of the surgery, which disrupts both muscular and bony structures. The pain is multifactorial, involving nociceptive (surgical site), neuropathic (nerve root irritation), and inflammatory components. A multimodal analgesic approach allows clinicians to address these multiple pain pathways simultaneously, providing more comprehensive pain relief. This postoperative pain can adversely affect the recovery process, prolong hospital stays, and reduce the overall quality of life for patients [3, 4]. Therefore, effective postoperative pain management is critical for enhancing recovery outcomes and patient satisfaction following lumbar spinal surgery [5].

Despite advancements in surgical techniques, managing postoperative pain remains a significant challenge. Traditional pain management strategies often rely heavily on opioid analgesics. Opioid use in spinal surgery is common due to the intensity of postoperative pain. However, excessive opioid use is associated with numerous side effects, delayed recovery, and increased risk of complications like opioid-induced respiratory depression. This has prompted the exploration of alternative analgesic methods that can provide effective pain relief with fewer side effects.

Multimodal analgesia is a key concept in modern pain management, particularly in the context of major surgeries like spinal procedures. It involves the use of different classes of analgesics and regional techniques to target various pain pathways, thereby reducing reliance on any single form of analgesia, especially opioids. This approach is designed to improve pain relief while minimizing the side effects associated with higher doses of opioids, such as nausea, vomiting, constipation, respiratory depression, and the risk of addiction [6].

By integrating regional techniques such as Erector Spinae Plane Block (ESPB) or Wound Infiltration (WI) into a multimodal regimen, clinicians can reduce total opioid consumption. For example, ESPB has demonstrated opioid-sparing effects, allowing for less reliance on systemic opioids, thus decreasing the incidence of opioid-related side effects [7, 8]. Effective pain control is crucial for early mobilization, which is a key factor in enhanced recovery after surgery (ERAS) protocols. Spinal surgeries often require patients to ambulate early to prevent complications such as deep vein thrombosis (DVT)

and to promote spinal healing and function. Inadequate pain control, indicated by high VAS scores, can delay mobilization and prolong hospital stays. A multimodal approach that includes regional anesthesia like ESPB or WI contributes to better pain control, which can support early mobilization, decrease hospital length of stay, and improve overall recovery outcomes.

Poorly managed acute postoperative pain is a known risk factor for the development of chronic pain. Patients undergoing spinal surgeries are particularly vulnerable to chronic postoperative pain, which can significantly impair their quality of life. Multimodal analgesia, by improving acute pain management, reduces this risk. Regional techniques like ESPB may be especially beneficial in this regard due to their potential for providing long-lasting pain relief beyond the immediate postoperative period.

The comparison between ESPB and WI in lumbar spinal surgeries is clinically significant within this multimodal framework. Both techniques aim to reduce postoperative pain and opioid consumption, but they do so through different mechanisms. Erector Spinae Plane Block (ESPB) is a relatively novel regional technique that provides broad analgesia by blocking both dorsal and ventral rami of the spinal nerves [9, 10]. This can result in extensive pain relief, covering both the somatic and visceral components of spinal surgery pain. ESPB's opioid-sparing effect also makes it an attractive option in multimodal protocols, particularly for complex surgeries requiring prolonged pain relief [11, 12].

WI is a more straightforward technique that involves injecting local anesthetics directly into the surgical wound, providing targeted analgesia at the incision site. While effective for controlling immediate postoperative pain, WI generally has a shorter duration of analgesic effect compared to ESPB, which may result in earlier opioid consumption and less effective long-term pain control [13, 14].

Given the growing interest in these techniques, evaluating their comparative efficacy in specific surgical contexts is essential. The primary aim of this study was to compare the efficacy of ultrasound-guided erector spinae plane block and wound infiltration in terms of postoperative analgesia in lumbar spinal surgeries involving instrumentation. Specifically, this study will assess the impact of these techniques on postoperative pain scores, analgesic consumption, incidence of side effects, and overall patient satisfaction [15].

By elucidating the relative advantages and limitations of ESPB and WI, this study aims to inform clinical practice and contribute to the optimization of postoperative pain management strategies in lumbar spinal surgery. Our findings are expected to guide clinicians in selecting the most effective pain management technique, ultimately improving patient outcomes and enhancing recovery processes [16].

Materials and methods

Study design

This randomized controlled study was conducted between May 1, 2023 and June 30, 2023, following the guidelines of the Helsinki Declaration. Approval for the study was obtained from our Institutional Hospital Research Ethics Committee on May 29, 2023 (approval number 2023/514/250/15). The first participant was enrolled on May 1, 2023 and the date on which the last participant in this clinical study was examined or received an intervention to collect final data for the primary outcome measure was June 30, 2023. Informed consent was obtained from all participants. Additionally, the study adheres to the CONSORT guidelines to ensure transparency and rigor in reporting clinical trials.

Participants

Eligible participants were adults aged 18–70 years who were scheduled for elective lumbar spinal stabilization and fusion surgery with instrumentation. The inclusion criteria were as follows:

- Elective lumbar spine surgery involving instrumentation
- ASA physical status I-III
- Ability to provide informed consent

The exclusion criteria were as follows:

- Known allergies to local anesthetics
- Coagulopathy or anticoagulant therapy
- Infection at the injection site
- Preexisting neurological disorders affecting sensory perception
- Pregnancy
- Inability to understand the visual analog scale (VAS) for pain assessment

The participants were randomly allocated into one of two groups: the ESPB group (Group E) or the WI group (Group W) (Fig. 1).

Randomization and blinding

A computer-generated random number sequence was used for randomization via IBM® SPSS version 25.0 to allocate participants into either the ESPB group (Group E) or the wound infiltration group (Group W) to ensure that each participant had an equal chance of being assigned to either group. This method minimizes

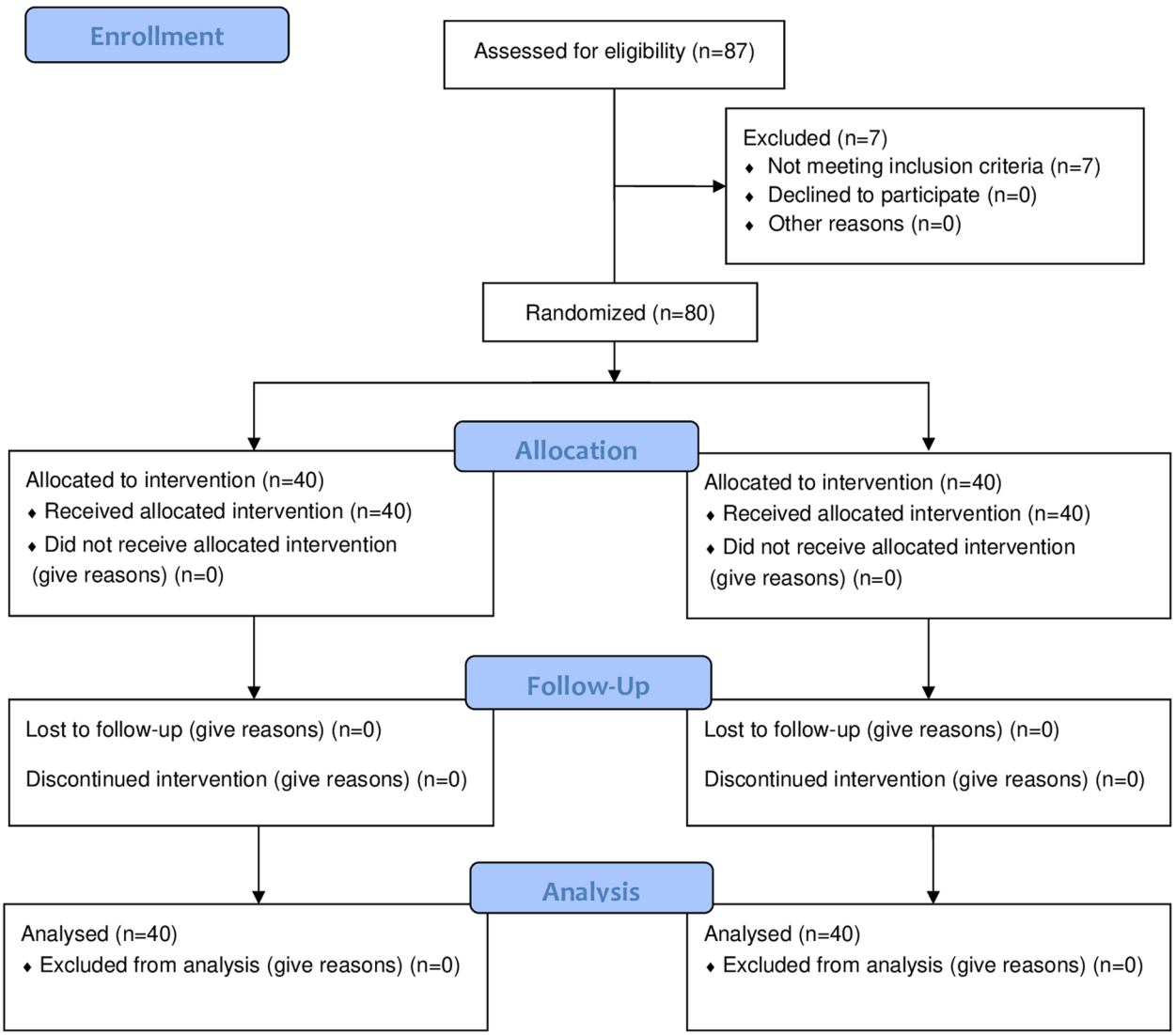

Fig. 1 CONSORT diagram

selection bias and enhances the internal validity of the study.

Allocation concealment

The randomization process was concealed through the use of sealed, opaque envelopes, which were opened just before the intervention. This technique ensured that neither the participants nor the outcome assessors were aware of the group assignments before the intervention, maintaining the blinding.

Stratification

No explicit stratification was employed in the randomization process. Stratified randomization is often used in clinical trials to ensure that important baseline characteristics, such as age, gender, or ASA (American Society of Anesthesiologists) physical status, are equally distributed between groups. In this study, however, the participants were randomized without stratification. Instead, baseline demographic characteristics, including sex, age, and ASA status, were compared between the groups after randomization, and no significant differences were found ($p > 0.05$), suggesting that randomization effectively balanced these factors between groups.

Blinding

While the anesthesiologist who administered the block knew the group allocation, both the patients and the research assistants responsible for postoperative assessments were blinded to the group assignments. This

double-blind design further minimized the risk of bias in outcome measurement.

Anesthesia protocol

All patients underwent a standardized general anesthesia protocol. Prior to induction, standard monitoring, including electrocardiography, non-invasive blood pressure, pulse oximetry, and capnography, was applied. General anesthesia was induced with intravenous propofol (2–2.5 mg/kg), fentanyl (1–2 mcg/kg), and rocuronium (0.6 mg/kg) to facilitate tracheal intubation. After intubation, invasive blood pressure monitoring was initiated via arterial cannulation, typically in the radial artery, for continuous hemodynamic monitoring throughout the procedure.

Maintenance of anesthesia was achieved using a combination of sevoflurane (1–2 MAC) in an oxygen/air mixture (FiO_2 50%) and continuous infusion of remifentanil (0.05–0.2 mcg/kg/min) to ensure adequate depth of anesthesia and hemodynamic stability. Intraoperative analgesia was supplemented with boluses of fentanyl as required. At the end of the procedure, neuromuscular blockade was reversed with neostigmine (0.05 mg/kg) and atropine (0.02 mg/kg), and patients were extubated once adequate spontaneous breathing was confirmed.

Interventions

Erector spinae plane block (Group E)

ESPB was administered on L2-3 level preoperatively under ultrasound guidance via a high-frequency linear probe (Sonosite M-Turbo, Fujifilm Sonosite® Inc., USA) bilaterally (Fig. 2). The following safety measures were implemented to ensure accurate and safe execution of the block:

1. Patient Positioning: Patients were placed in the lateral decubitus position, which provides better access to the lumbar area and facilitates safe needle insertion. The surgical side was kept uppermost to optimize visibility and access.
2. Ultrasound Setup: A high-frequency linear ultrasound probe was used to identify the relevant anatomical landmarks, specifically the transverse processes of the lumbar vertebrae at the level of surgery. The probe was positioned in a parasagittal orientation to visualize the transverse process and surrounding muscles, ensuring clear identification of the injection site.
3. Needle Insertion:
    - o A 22-gauge, 100-mm needle (Stimuplex® A, B. Braun Melsungen AG, Germany) was inserted in-plane with the ultrasound probe. The in-plane technique was employed to allow continuous visualization of the needle tip throughout the procedure, reducing the risk of accidental injury to nearby structures.
    - o The needle was advanced cautiously until the tip made contact with the transverse process, confirming proper placement.

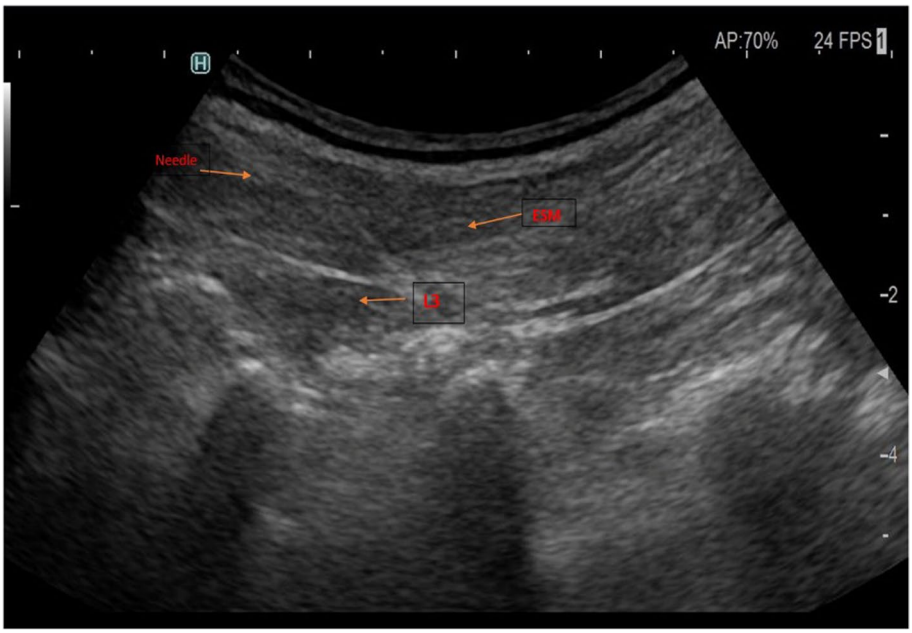

Fig. 2 ESP block performed via ultrasonication guidance

- Safety Check (Aspiration): After the needle reached the correct position, negative aspiration was performed to confirm that the needle was not within a blood vessel, reducing the risk of intravascular injection.

4. Injection: Once the needle was correctly positioned, 20 mL of 0.5% bupivacaine was injected incrementally, with real-time ultrasound guidance to confirm the spread of the local anesthetic around the target area. Visualization of the anesthetic spread ensured that the drug was delivered to the correct plane, maximizing analgesic efficacy while minimizing the risk of complications.
5. Monitoring: Patients were monitored closely for any signs of complications, such as local anesthetic systemic toxicity (LAST), which can occur with regional blocks if the anesthetic is injected intravascularly. Monitoring included continuous cardiovascular and respiratory assessment during and after the procedure.

The use of ultrasound guidance is a crucial safety measure in ESPB, as it allows for real-time visualization of the needle and surrounding anatomical structures, thereby reducing the risk of nerve injury, vascular puncture, and other complications. The in-plane needle insertion technique further enhances safety by ensuring that the entire needle pathway is visible during the procedure. These precautions are especially important for lumbar spinal surgeries where delicate structures are in close proximity.

Wound infiltration (Group WI)

Wound infiltration was performed by the surgeon at the end of the surgery via the following procedure:

1. Preparation: After hemostasis was achieved and before skin closure, 20 mL of 0.5% bupivacaine was prepared in a sterile syringe.
2. For infiltration, the anesthetic mixture was infiltrated into multiple layers of the surgical wound. This included the subcutaneous tissue and muscle layers, ensuring the even distribution of the anesthetic solution to cover the entire surgical area.

Outcome measures

The primary and secondary outcome measures were as follows:

Primary outcome measure:

- Pain Score Evaluation: Postoperative pain intensity was assessed using the visual analog scale (VAS) at predetermined time points (1, 6, 12, and 24 h postoperatively). The pain scores were evaluated by trained research nurses who were blinded to the patients' group allocations to ensure unbiased assessment. These nurses were not involved in the administration of anesthesia or postoperative care, and they followed a standardized protocol for VAS evaluation. All patients were asked to rate their pain by marking a point on the 10 cm VAS scale, where 0 represented no pain and 10 represented the worst pain imaginable.

Secondary outcome measures:

- Total Opioid Consumption: Recorded as morphine equivalents in the first 48 h postoperatively.
- Time to first request for rescue analgesia: Noted in hours postoperatively.
- Incidence of Side Effects: Including nausea, vomiting, pruritus, and urinary retention, recorded as binary outcomes (present/absent).
- Patient Satisfaction with Pain Management: Patient satisfaction was assessed via Turkish version of Revised American Pain Society Patient Outcome Questionnaire (APS-POQ-R-TR).

Pain management protocol

After surgery, all patients received a standardized postoperative pain management protocol. This included the administration of intravenous paracetamol (1 g every 6 h) and rescue analgesia with intravenous tramadol (100 mg) when the visual analog scale (VAS) score exceeded 4. Additional analgesics, such as non-steroidal anti-inflammatory drugs (NSAIDs), were administered if necessary, following clinical judgment. The protocol aimed to maintain adequate pain control while minimizing opioid consumption, with all patients closely monitored for pain levels, side effects, and overall recovery.

Data collection

Data were collected by trained research assistants who were blinded to the group assignments. Pain scores were recorded via the VAS at the specified postoperative intervals. Opioid consumption was documented from the patients' medical records. Side effects were monitored and recorded by the nursing staff. Patient satisfaction was assessed through the Turkish version of the APS-POQ-R (APS-POQ-R-TR). American Pain Association created APS-POQ-R in 1991 and revised it in 2010 with patient satisfaction related elements [17]. The validity and reliability study for the Turkish language version of the questionnaire (APS-POQ-R-TR) was performed by Erden et al. [18].

Power analysis

A power analysis was conducted to determine the appropriate sample size for the study. The analysis was based on detecting a clinically significant difference in the VAS score between the two groups. Assuming a mean difference of 1.5 points in the VAS score with a standard deviation of 2.0, an alpha level of 0.05, and a power of 80%, the required sample size was calculated as follows:

$$n = \left(\frac{Z_{\alpha/2} + Z_{\beta} \cdot \sigma}{\Delta} \right)^2$$

where:

- n = required sample size per group
- $Z_{\alpha/2}$ = Zvalue for the desired confidence level (1.96 for 95% confidence)
- Z_{β} = Z-value for the desired power (0.84 for 80% power)
- σ = standard deviation (2.0)
- Δ = mean difference to be detected (1.5)

The values are as follows:

$$n = \left(\frac{1.96 + 0.84 \times 2.0}{1.5} \right)^2 = 33.7$$

To account for potential dropouts and incomplete data, we aimed to enroll 40 patients per group, resulting in a total sample size of 80 participants.

Statistical analysis

Continuous variables are presented as the means ± standard deviations and were analyzed via Student's t test for normally distributed data or the Mann–Whitney U test for nonnormally distributed data. Categorical variables are presented as frequencies and percentages and were analyzed via the chi-square test or Fisher's exact test, as appropriate. A p value of <0.05 was considered to indicate statistical significance. All the statistical analyses were performed via SPSS®, version 25.0 (IBM Corp., Armonk, NY, USA).

Results

Demographic and clinical characteristics

The study included a total of 80 patients, with 40 patients in the ESP block group (Group E) and 40 patients in the wound infiltration group (Group W). The demographic and clinical characteristics of the participants are summarized in Table 1. There were no significant differences between the groups in terms of sex, age, or body mass index (BMI).

ASA physical status and surgical details

The American Society of Anesthesiologists (ASA) physical status and surgical duration are presented in Table 2. No significant differences were observed between the two groups in terms of ASA physical status or the duration of surgery.

Postoperative pain scores

Postoperative pain intensity was assessed via the visual analog scale (VAS) at various time points. The results are shown in Table 3. The mean VAS scores at 30 min, 1 h, 2 h, 4 h, 8 h, 12 h, and 24 h postoperatively were not significantly different between the ESP block group and the wound infiltration group. (Figs. 3 and 4).

Additional outcomes

In this study, no serious complications such as LAST, pneumothorax, or nerve injury were reported, though minor issues like transient discomfort at the injection site may have occurred in ESPB group. Continuous monitoring post-procedure ensured early detection of any adverse events. In addition, the injection of large volumes of local anesthetic can lead to temporary tissue edema, which may slightly delay wound healing in WI group. This is generally a rare occurrence and was not observed in the current study. These reinforce the general safety of both techniques when performed by experienced clinicians.

Other postoperative outcomes, including postoperative nausea and vomiting (PONV), time to first rescue analgesic, and total consumption of paracetamol and tramadol are summarized in Table 4.

For consistency and ease of comparison across studies, presenting total opioid consumption in morphine

Table 1 The demographic and clinical characteristics of the participants

Variable	ESP Block ($n=40$)	Wound Infiltration (WI) ($n=40$)	p value
Female, n (%)	30 (75%)	25 (62.5%)	0.245 (cs = 1.352)
Male, n (%)	10 (25%)	15 (37.5%)	
Age Mean ± SD	58.3 ± 6.5	56.7 ± 7.8	0.270 (z = -1.101)
Age Range (min–max)	43—68	39—69	
BMI Mean ± SD	26.30 ± 2.10	26.15 ± 1.70	0.700 (t = 0.386)
BMI Range (min–max)	22.03—30.0	23.03—29.5	

Table 2 The American Society of Anesthesiologists (ASA) physical status and surgical duration

Variable	ESP Block ($n=40$)	Wound Infiltration (WI) ($n=40$)	p value
ASA Mean ± SD	2.35 ± 0.58	2.22 ± 0.56	0.296 (z = -1.046)
ASA Range (min–max)	1—3	1—3	
1, n (%)	3 (7.5%)	4 (10%)	0.694 (cs = 0.364)
2, n (%)	22 (55%)	23 (57.5%)	
3, n (%)	15 (37.5%)	13 (32.5%)	
Surgical Duration Mean ± SD	3.75 ± 0.95	3.70 ± 0.90	0.778 (t = 0.282)
Surgical Duration Range (min–max)	2—6	2—6	

Table 3 Comparison of the mean VAS scores between groups

Time Point	ESP Block ($n=40$)	Wound Infiltration (WI) ($n=40$)	Intergroup p value
VAS 30 min Mean ± SD	4.30 ± 2.70	5.00 ± 2.20	0.300 (t = -1.04)
VAS 1 h Mean ± SD	4.75 ± 2.50	5.50 ± 2.55	0.330 (t = -0.97)
VAS 2 h Mean ± SD	4.85 ± 2.60	5.55 ± 2.45	0.140 (t = -1.48)
VAS 4 h Mean ± SD	4.85 ± 2.10	5.05 ± 2.45	0.340 (t = -0.95)
VAS 8 h Mean ± SD	4.00 ± 2.05	4.15 ± 2.40	0.730 (t = -0.35)
VAS 12 h Mean ± SD	3.05 ± 1.45	3.50 ± 2.05	0.240 (t = -1.18)
VAS 24 h Mean ± SD	2.35 ± 1.30	2.60 ± 1.40	0.350 (t = -0.93)

The intragroup p values for changes in VAS scores over time were significant for both groups ($p=0.0001$), indicating significant reductions in pain scores over the 24-h postoperative period

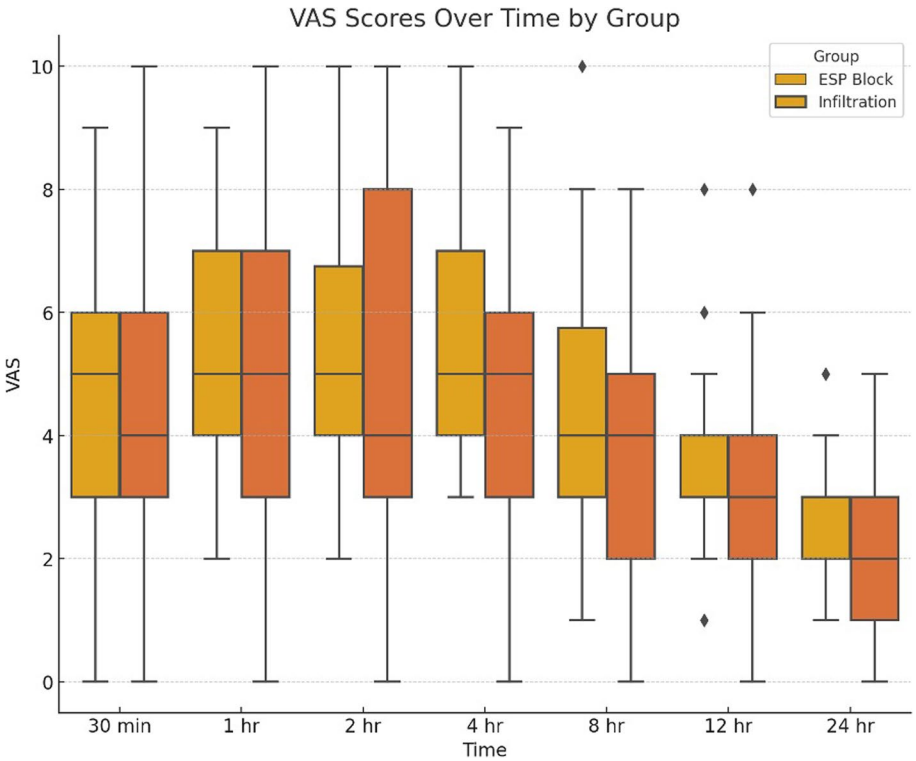

Fig. 3 Vas scores over time by group

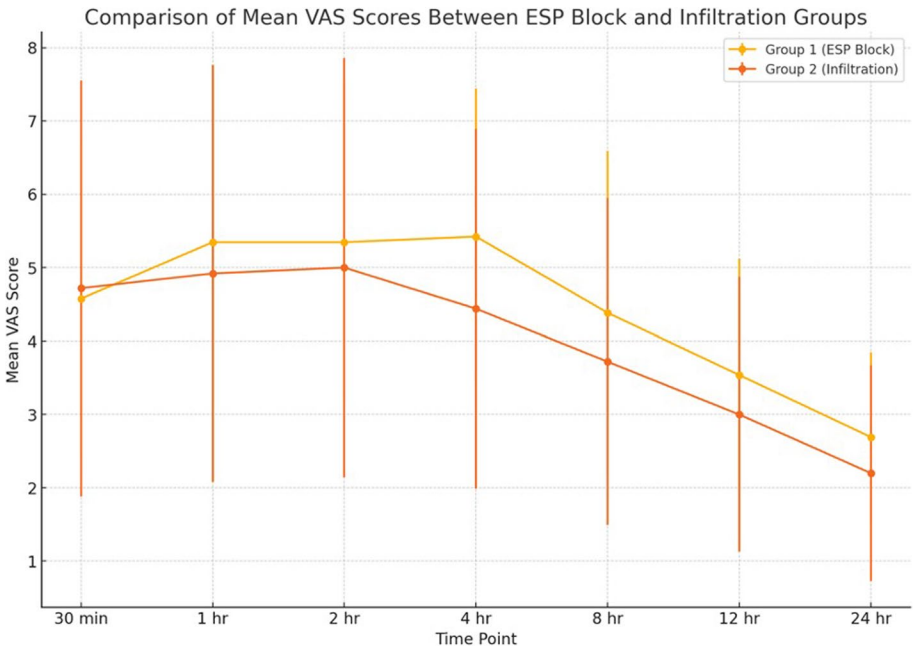

Fig. 4 Comparison of the mean VAS scores between the ESP block and wound infiltration groups

equivalents is indeed a common and effective approach. This standardization allows the reader to better interpret the opioid-sparing effects of the interventions (ESPB vs. WI), as different types of opioids (such as tramadol, fentanyl, or morphine) have varying potencies.

To convert tramadol (the opioid used in this study) into morphine equivalents, the typical conversion factor is:

- 100 mg of tramadol ≈ 10 mg of oral morphine (approximately a 10:1 ratio).

Therefore, the total tramadol consumption in the ESPB group (50 ± 60 mg) and the WI group (100 ± 75 mg) can be roughly converted into morphine equivalents:

- ESPB group: 50 mg of tramadol ≈ 5 mg of oral morphine
- WI group: 100 mg of tramadol ≈ 10 mg of oral morphine

Postoperative pain scores

Postoperative pain intensity was assessed via the visual analog scale (VAS) at various time points. The results, summarized in Table 3, revealed that there were no statistically significant differences in the mean VAS scores between the ESP block and wound infiltration groups at any of the assessed time points (30 min, 1 h, 2 h, 4 h, 8 h, 12 h, and 24 h postoperatively). These findings suggest that both analgesic techniques are similarly effective in managing postoperative pain during the first 24 h.

The VAS scores in both groups were relatively high, with mean scores > 4.0 at several time points, which suggests that pain management may have been inadequate during certain postoperative periods. This

Table 4 Comparison of the postoperative outcomes between the groups

Outcome	ESP Block ($n = 40$)	Wound Infiltration (WI) ($n = 40$)	Intergroup p value
Postop PONV (0–2)	0.25 ± 0.70	0.50 ± 0.75	0.095 (t = -1.69)
First Rescue Analgesic (hrs)	3.40 ± 3.00	1.85 ± 2.60	0.045* (t = -2.00)
Total Paracetamol (g)	0.70 ± 0.55	0.95 ± 0.50	0.080 (t = -1.74)
Total Tramadol (mg)	50 ± 60.00	100 ± 75.00	0.010* (t = -2.53)

SD Standard deviation, t Independent samples ttest

* $p < 0.05$ statistically significant

underscores the need for further optimization of the analgesia protocols used in both groups.

Pain management protocol

- ESPB Group (Erector Spinae Plane Block): Patients in the ESPB group received a single preoperative dose of 20 mL of 0.5% bupivacaine administered via ultrasound-guided ESP block. No additional regional analgesia was provided postoperatively. Standard postoperative analgesia included intravenous paracetamol and rescue tramadol if the VAS score exceeded 4.0.
- WI Group (Wound Infiltration): In the WI group, 20 mL of 0.5% bupivacaine was infiltrated into the wound at the end of surgery. Standard postoperative analgesia consisted of intravenous paracetamol and rescue tramadol, administered when the VAS score exceeded 4.0.

Intragroup comparisons revealed statistically significant reductions in VAS scores over time ($p=0.0001$) in both groups, indicating some improvement in pain levels. However, the persistently high VAS scores (VAS > 4.0) at multiple time points suggest that the pain management protocol may have been suboptimal, warranting further refinement of postoperative analgesia strategies in these patients.

Discussion

General evaluation

This study aimed to compare the efficacy of ultrasound-guided erector spinae plane block (ESPB) with that of wound infiltration (WI) for postoperative analgesia in lumbar spinal surgeries involving instrumentation. Our findings demonstrate that ESPB is very effective in providing postoperative pain relief because it lowered the time it takes to rescue analgesia and lowered total opioid consumption. These results are in line with those of previous studies, such as those by Yayik et al. and Gișı et al., which reported the effectiveness of ESPB in various types of spinal surgeries [5, 7, 19, 20]. These findings underscore the potential advantages of ESPB in managing postoperative pain, particularly in complex surgical settings where prolonged pain relief is crucial.

Analgesic efficacy

The primary outcome, postoperative pain intensity measured by the visual analog scale (VAS), revealed no significant differences between ESPB and WI at any postoperative time point (30 min, 1 h, 2 h, 4 h, 8 h, 12 h, or 24 h). These results are consistent with those of prior studies, such as those of Forero et al. (2016), who demonstrated that ESPB offers effective analgesia comparable to traditional infiltration methods in thoracic and abdominal surgeries [5]. Similarly, Chin et al. (2017) reported no significant difference in VAS scores between ESPB and alternative regional anesthesia techniques in hip surgery [7]. Despite the comparable VAS scores, the clinical implications are significant, as ESPB's ability to provide prolonged analgesia and reduce the need for rescue analgesia offers a clear advantage in postoperative pain management.

In addition to VAS scores, the literature supports the versatility and reliability of ESPB as a regional anesthesia technique across different surgical contexts. For example, studies by Chiraya et al. (2023) and Ueshima et al. (2019) have shown that ESPB significantly reduces opioid requirements in thoracolumbar and lumbar spinal surgeries, respectively, which aligns with our findings of reduced tramadol consumption [21, 22]. The reduction in opioid use, even without significant changes in VAS scores, suggests that ESPB may offer benefits beyond simple pain relief, potentially enhancing overall patient recovery and satisfaction.

Time to first rescue analgesia

The time to first request for rescue analgesia was significantly longer in the ESPB group than in the WI group (3.40 ± 3.00 h vs. 1.85 ± 2.60 h, $p=0.045$). This finding indicates that ESPB provides a more prolonged analgesic effect, which can be advantageous in minimizing the need for additional analgesic interventions and enhancing patient comfort during the immediate postoperative period. Tulgar et al. (2018) highlighted the extended duration of analgesia associated with ESPB due to the distribution of local anesthetics in the paravertebral space [8]. The extended analgesic effect of ESPB not only enhances patient satisfaction but also reduces the workload of healthcare providers.

The prolonged duration before the need for rescue analgesia is clinically significant, particularly within multimodal analgesia strategies. Prolonged analgesia can contribute to reduced overall opioid and analgesic consumption, thereby mitigating the risk of adverse effects and promoting faster recovery. This finding is particularly relevant given the current opioid crisis, where reducing opioid consumption is a critical component of postoperative pain management.

Opioid consumption

A significant reduction in total tramadol consumption was observed in the ESPB group compared with the WI group (50 ± 60.00 mg vs. 100 ± 75.00 mg, $p=0.010$). This opioid-sparing effect is clinically important, as it minimizes the incidence of opioid-related side effects, including nausea, vomiting, pruritus, and respiratory depression, which are major concerns in postoperative care. The opioid-sparing effect of ESPB has been well documented in the literature.

For example, Ueshima and Otake (2017) reported significantly lower postoperative opioid requirements with ESPB in pneumothorax surgery [6].

Similarly, Wang et al. (2019) reported that, compared with WI, ESPB reduced perioperative opioid consumption in thoracotomy patients, which supports our findings. The reduction in opioid use is particularly significant given the current opioid crisis, where minimizing opioid consumption is a key objective in postoperative pain management [23].

The finding that VAS scores were not significantly different between the ESPB and wound infiltration groups, despite ESPB reducing opioid consumption and prolonging analgesia, is crucial. This can be explained by the following:

1. Mechanism of ESPB: ESPB works by providing a wider range of analgesia than wound infiltration, covering multiple dermatomes. This could lead to more effective background pain control, even though the immediate VAS scores reflect a similar level of pain perception in both groups at discrete time points.
2. Opioid-sparing effect: ESPB's ability to reduce opioid consumption is a significant advantage. Reduced opioid use could prevent opioid-induced side effects like nausea and vomiting, which are not directly measured by VAS but significantly impact patient comfort and recovery. This opioid-sparing effect, despite similar pain scores, may account for the enhanced patient recovery and prolonged analgesic effect without the need for as many rescue analgesics.
3. Prolonged analgesic duration: The longer-lasting analgesia observed with ESPB means that patients are likely experiencing less breakthrough pain and fewer fluctuations in pain intensity over time. Even if the VAS scores are not significantly different, the quality of pain control could be superior with ESPB due to fewer analgesic interventions being necessary throughout the postoperative period.
4. Patient satisfaction and clinical outcomes: Although VAS scores are important for measuring pain intensity, the reduction in opioid consumption and need for rescue analgesics may enhance overall patient satisfaction and recovery experience. This is a key aspect of postoperative care, where multimodal pain strategies, such as ESPB, can offer benefits that go beyond what is captured by VAS alone.

Postoperative nausea and vomiting (PONV)

While the incidence of PONV was greater in the WI group, the difference did not reach statistical significance (0.50 ± 0.75 vs. 0.25 ± 0.70, $p = 0.095$). Nevertheless, the trend toward reduced PONV in the ESPB group could be attributed to lower opioid consumption, as noted by Wu and Raja (2011) [4]. Reducing PONV is a critical aspect of improving patient satisfaction and comfort postoperatively, as it significantly affects the overall recovery experience.

Our findings support the notion that regional anesthesia techniques such as ESPB, which are associated with reduced opioid consumption, may also lead to a lower incidence of PONV. This underscores the multifaceted benefits of ESPB beyond pain relief, including improvements in overall postoperative outcomes.

Patient satisfaction

Although patient-reported outcomes were not extensively measured in this study, the reduced need for rescue analgesia and lower opioid consumption in the ESPB group suggest the potential for greater patient satisfaction. Patient satisfaction is a crucial aspect of postoperative care and significantly impacts the perceived success of surgical interventions. Gordon DB et al. reported that effective pain management strategies, such as ESPB, can increase patient satisfaction and overall quality of life [17]. Future studies should incorporate detailed patient satisfaction surveys to more comprehensively evaluate the subjective benefits of ESPB compared with WI.

Clinical and economic implications

The clinical advantages of ESPB, including prolonged analgesia and reduced opioid consumption, have significant implications for postoperative pain management. Furthermore, the economic impact of ESPB is also worth considering. Cui Y et al. assessed the cost-effectiveness of ESPB, highlighting its potential financial benefits due to reduced opioid use and improved recovery outcomes [24]. The opioid-sparing effect of ESPB may lead to decreased healthcare costs associated with opioid-related side effects and faster patient recovery.

Here, it is important to address the cost factors associated with the use of ESPB, particularly the need for specialized equipment such as ultrasound machines, special needles, and the extra time required for administering the block under ultrasound guidance. These additional costs, in terms of both equipment and time, could be seen as a disadvantage, especially in resource-limited settings.

However, these upfront costs should be balanced against the long-term clinical and economic benefits demonstrated in this study. The significant reduction in opioid consumption and the prolonged analgesic effect observed in the ESPB group can translate into lower

overall healthcare costs. Fewer opioids mean a reduced risk of opioid-related side effects, such as postoperative nausea and vomiting (PONV), respiratory depression, and constipation, which can require additional treatments and lengthen hospital stays.

Moreover, the superior pain control provided by ESPB, as reflected in the longer time to first rescue analgesia and reduced need for rescue medications, may also contribute to earlier mobilization, fewer postoperative complications, and possibly shorter hospital stays. This can improve patient outcomes and potentially reduce costs related to extended hospital care and interventions for opioid-related side effects.

Ultimately, while the initial setup for ESPB may be more costly and time-intensive, the superior clinical outcomes—such as reduced opioid use, prolonged analgesia, and enhanced patient recovery—justify the investment. These advantages align with the goals of modern multimodal analgesia protocols and enhanced recovery after surgery (ERAS) protocols, which focus on minimizing opioid consumption and improving overall patient recovery. Therefore, the cost of implementing ESPB should be viewed not only in terms of immediate expenses but also in the context of potential long-term savings and improved patient outcomes.

Further studies evaluating the cost-effectiveness of ESPB in larger and more diverse surgical settings would provide more comprehensive insights into its economic viability as part of routine postoperative pain management.

Study limitations

This study has several limitations that should be acknowledged. First, the study was conducted at a single institution, which may limit the generalizability of the findings. Multicenter studies involving diverse patient populations and varying clinical practices are needed to validate these results and ensure their applicability across different healthcare settings.

Additionally, the follow-up period was limited to 24 h postoperatively. While this time frame is adequate for assessing immediate postoperative pain and analgesic needs, it does not capture longer-term outcomes such as chronic pain development or functional recovery. Extended follow-up periods in future studies could provide valuable insights into the long-term effects of ESPB and WI on patient recovery and overall outcomes. Furthermore, patient-reported outcomes, such as satisfaction and quality of life, were not extensively evaluated in this study. Incorporating comprehensive patient-reported measures in future research could offer a more complete understanding of the relative benefits of ESPB versus WI from the patient's perspective.

Another limitation of the study is the lack of a detailed cost-effectiveness analysis. Given the potential benefits of ESPB in reducing opioid consumption and improving recovery outcomes, an economic evaluation would be valuable in determining the feasibility of incorporating ESPB into standard pain management protocols. Additionally, the learning curve associated with ESPB was not assessed in this study. Understanding the training requirements and challenges in the widespread clinical adoption of ESPB is crucial for its effective implementation. Future studies should consider these aspects to ensure that ESPB can be efficiently and safely integrated into routine clinical practice.

Finally, the absence of a controlled group receiving standard analgesia without regional anesthesia is a further limitation of this study. This restricts our ability to evaluate the comparative efficacy of ESPB and wound infiltration against a baseline of conventional postoperative analgesia. Future studies should consider including a control group to provide a more comprehensive evaluation of these techniques in postoperative pain management.

Future directions

Future research should explore the long-term benefits of ESPB in various surgical populations, including its potential role in enhanced recovery protocols. Comparative studies involving other regional anesthesia techniques, such as transversus abdominis plane (TAP) block or paravertebral block (PVB), could provide valuable information on the relative efficacy of different regional anesthesia methods. Moreover, research into the combination of ESPB with other analgesic techniques may yield insights into optimizing pain management strategies for lumbar spinal surgeries and potentially other types of surgeries [25, 26].

Investigating the cost-effectiveness of ESPB compared with WI and other analgesic methods is also warranted. Understanding the economic implications will help determine the feasibility of adopting ESPB as a standard practice in postoperative pain management. Additionally, studies should examine the learning curve associated with ESPB to evaluate the necessary training and resources required for effective clinical implementation. This is particularly important for ensuring that ESPB can be safely and widely adopted in diverse clinical settings.

Finally, exploring the integration of ESPB into enhanced recovery after surgery (ERAS) protocols could provide insights into optimizing postoperative care and improving patient outcomes. Given its potential to offer effective pain relief with minimal side effects, ESPB may become an integral component of ERAS protocols, facilitating

early mobilization and discharge, which are key goals in modern perioperative care.

Conclusion

In conclusion, this study demonstrated that ESPB provides better analgesia than WI due to a longer time first to rescue opioid analgesia and lower total opioid consumption. These findings support the integration of ESPB into multimodal analgesia protocols to enhance postoperative pain management. By offering effective pain relief with fewer side effects, ESPB has the potential to improve patient satisfaction, contribute to better overall surgical outcomes, and reduce healthcare costs. Future research should focus on long-term benefits, cost-effectiveness, and the integration of ESPB into enhanced recovery protocols to maximize its clinical potential.

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Authors' contributions
Y.Y., C.O., T.S., S.A.K., O.S., B.C., and E.A. each contributed equally to the conception, creation, gathering, processing, and interpretation of the data. Y.Y. wrote the manuscript. The manuscript was extensively reviewed for significant intellectual content by Y.Y. and B.C. All of the authors authorized the final version of the manuscript for publication. To guarantee that any doubts regarding the precision or honesty of any portion of the work are duly examined and settled, Y.Y., C.O.,T.S., O.S., S.A.K., B.C., and E.A. consented to take complete responsibility for the project.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
University of Health Sciences Kartal Dr. Lutfi Kirdar City Hospital Research Ethics Committee approved our study on May 29, 2023 (2023/514/250/15). All patients signed a written informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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