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Erector Spinae Plane Block Versus Intrathecal Morphine for Post-Cesarean Analgesia Within an Enhanced Recovery Protocol: A Randomized Controlled Trial

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Abstract | **Original Research Article**

Background: Optimal post-cesarean analgesia is essential for successful Enhanced Recovery After Surgery (ERAS) protocols. While intrathecal morphine remains the gold standard, its adverse effects limit widespread use. The erector spinae plane (ESP) block has emerged as a promising opioid-sparing alternative. This study compared the analgesic efficacy and safety profile of ESP block versus intrathecal morphine in a multimodal ERAS pathway. ***Methods:*** This prospective, randomized, single-blind study enrolled 140 parturients undergoing elective cesarean delivery under spinal anesthesia at a tertiary care center in Algeria (February 2023–December 2024). Patients were randomly allocated to receive either bilateral ESP block at T9 with 20 mL of 0.25% bupivacaine per side (ESP group, n=70) or intrathecal morphine 100 µg (Morphine group, n=70). Both groups received standardized multimodal analgesia with paracetamol and nefopam. Primary outcome was time to first analgesic request. Secondary outcomes included visual analog scale (VAS) scores at rest and during mobilization, rescue analgesic consumption, adverse effects, maternal satisfaction, and length of hospital stay. Multivariate analyses identified independent predictors of analgesic requirements. ***Results:*** The ESP group demonstrated significantly prolonged time to first analgesic request compared to the Morphine group (median 16h vs 6h; mean 16.88±5.09h vs 6.86±3.43h; $p<10^{-17}$). VAS scores were consistently lower in the ESP group at rest at H2, H4, H6, H8, and H24 (all $p<0.05$), and during movement at H6, H8, and H24 (all $p<0.05$). Rescue analgesic requirements were significantly reduced in the ESP group: paracetamol consumption (601.6 mg vs 1310.8 mg, $p<0.001$) and nefopam consumption (1.72 mg vs 9.42 mg, $p<0.001$). The ESP group exhibited markedly lower rates of postoperative nausea and vomiting (22.9% vs 65.7%, $p<0.001$), pruritus (17.1% vs 81.4%, $p<0.001$), and urinary retention (0% vs 14.3%, $p=0.003$). No respiratory depression occurred in either group. Maternal satisfaction was significantly higher in the ESP group (84.3% vs 62.9% "very satisfied", $p=0.014$). Mean hospital stay was shorter with ESP block (26.74±5.84h vs 29.31±8.08h, $p=0.03$), with higher rates of discharge at 24 hours (80% vs 65.7%, $p=0.041$). Multivariate analysis revealed that analgesic technique was the only independent predictor of time to first analgesic request, with ESP block prolonging analgesia by 9.4 hours (95% CI: 7.8–11.1, $p<0.001$) regardless of maternal demographics or obstetric characteristics. ***Conclusions:*** Bilateral ESP block provides superior analgesia, markedly reduces opioid-related adverse effects, enhances maternal satisfaction, and facilitates earlier hospital discharge compared to intrathecal morphine after cesarean delivery. These findings support the integration of ESP block as a cornerstone technique in ERAS protocols for cesarean section, offering a safe and effective opioid-sparing strategy.

Keywords: Erector spinae plane block; Intrathecal morphine; Cesarean section; Enhanced recovery after surgery; Postoperative analgesia; Opioid-sparing; Multimodal analgesia.

INTRODUCTION

Cesarean delivery (CD) is one of the most commonly performed surgical procedures worldwide, with rates continuing to rise globally. [1,2] Post-cesarean pain management represents a critical component of maternal care, significantly influencing recovery, mobility, breastfeeding success, and mother-infant bonding. [3,4] Inadequate pain control can lead to chronic post-surgical pain, delayed functional recovery, and compromised maternal satisfaction. [5,6]

Enhanced Recovery After Surgery (ERAS) protocols have revolutionized perioperative care across surgical specialties, including obstetrics.[7,8] These evidence-based, multimodal pathways aim to optimize patient outcomes, accelerate recovery, and reduce healthcare costs.[9] Effective analgesia constitutes a fundamental pillar of ERAS protocols, enabling early mobilization, oral intake, and hospital discharge while minimizing opioid-related complications. [10,11]

Intrathecal morphine has long been considered the gold standard for post-cesarean analgesia, providing prolonged pain relief through central neuraxial mechanisms.[12,13] However, its use is associated with significant adverse effects including nausea, vomiting, pruritus, urinary retention, and the rare but serious complication of delayed respiratory depression.[14,15] These side effects can impede ERAS pathway implementation and may delay maternal recovery.[16]

The erector spinae plane (ESP) block, first described by Forero *et al.,* in 2016,[17] has emerged as a promising alternative regional anesthetic technique. This interfascial plane block provides thoraco-abdominal analgesia through local anesthetic deposition in the fascial plane deep to the erector spinae muscle.[18,19] The technique offers several theoretical advantages: relative technical simplicity, favorable safety profile, and dermatomal coverage extending both cranially and caudally from the injection site.[20,21] Preliminary evidence suggests ESP block may provide effective post-cesarean analgesia with fewer opioid-related complications.[22-24]

Despite growing interest, high-quality comparative data evaluating ESP block against intrathecal morphine in the context of comprehensive ERAS protocols remain limited, particularly from resource-limited settings in North Africa. Furthermore, most existing studies have not employed truly opioid-free rescue analgesia in the ESP group, potentially confounding comparative efficacy assessments.[25,26]

This randomized controlled trial was designed to compare the analgesic efficacy, safety profile, and impact on maternal recovery of bilateral ESP block versus intrathecal morphine in parturients undergoing elective cesarean delivery within a standardized ERAS protocol. Uniquely, our study employed complete opioid exclusion in the ESP group's rescue analgesia regimen, utilized comprehensive multivariate analyses to identify independent predictors of analgesic requirements, and evaluated outcomes in a North African population where such data are scarce.

We hypothesized that ESP block would provide non-inferior analgesia to intrathecal morphine while demonstrating superior safety profile, reduced opioid-related adverse effects, and enhanced compatibility with ERAS pathway objectives.

METHODS

Study Design and Ethical Approval

This prospective, randomized, single-blind, parallel-group superiority trial was conducted at the Mother and Child Specialized Hospital of Ouargla, Algeria, between February 25, 2023, and December 25, 2024. The study protocol was reviewed and approved by the local Ethics Committee [reference number to be inserted] and registered with [clinical trial registry to be inserted]. The study was conducted in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines.

Participants

Inclusion criteria:

Parturients aged ≥16 years scheduled for elective cesarean delivery under spinal anesthesia with American Society of Anesthesiologists (ASA) physical status I-II were eligible. Additional requirements included non-hemorrhagic delivery, availability of telephone contact, access to medical care if needed post-discharge, and not living alone.

Exclusion criteria:

Parturients with ASA ≥3; severe or poorly controlled comorbidities (cardiac, pulmonary, diabetes, immunosuppression, coagulopathy, therapeutic anticoagulation, long-term corticosteroid therapy); contraindications to neuraxial anesthesia; pregnancy-related complications (pre-eclampsia and its complications); and inability to contact healthcare providers if needed.

All eligible patients received comprehensive oral and written information about the study. Written informed consent was obtained from all participants before enrollment.

Sample Size Calculation

Sample size was calculated using XLSTAT 2014.5.03 based on preliminary data showing mean time to first analgesic request of 4.93±0.82 hours in the morphine group versus 12±2.81 hours in the ESP group. With α=0.01 (one-tailed), power=0.99, and accounting for 10% attrition, the calculated requirement was 31 patients per group. To enhance statistical power and generalizability, we expanded enrollment to 74 patients, ultimately recruiting 140 patients (70 per group) to ensure robust conclusions.

Randomization and Blinding

Patients were randomly allocated in a 1:1 ratio to either the ESP block group or the Morphine group using computer-generated randomization sequences concealed in sequentially numbered, opaque envelopes. Randomization was performed by a researcher not involved in patient care or outcome assessment. Due to the nature of the interventions (neuraxial versus ultrasound-guided peripheral block), anesthesiologists performing the procedures could not be blinded.

However, postoperative pain assessments and data collection were performed by nurses blinded to group allocation.

Anesthetic Management

Preoperative Phase

All patients received standardized preoperative preparation according to ERAS guidelines : [27,28]

- Clear liquids permitted until 2 hours before surgery; solids until 6 hours
- Antibiotic prophylaxis: cefazolin 2 g or amoxicillin-clavulanic acid 2 g IV within 30 minutes before skin incision
- Antiemetic prophylaxis: metoclopramide 10 mg IV
- Dexamethasone 8 mg IV (anti-inflammatory and antiemetic properties)

Intraoperative Management

Standard monitoring included non-invasive blood pressure, heart rate, pulse oximetry, and electrocardiography. All patients received spinal anesthesia in the sitting position using a 27G pencil-point needle at the L3-L4 or L4-L5 interspace.

Morphine Group: Spinal anesthesia with hyperbaric bupivacaine 0.5% 10 mg + fentanyl 25 µg + morphine 100 µg

ESP Block Group: Spinal anesthesia with hyperbaric bupivacaine 0.5% 10 mg + fentanyl 25 µg (no intrathecal morphine)

Following delivery and uterine closure, patients in the ESP group received bilateral ultrasound-guided ESP block at the T9 level in the lateral position. Using a high-frequency linear ultrasound probe (7-12 MHz), the transverse process of T9 was identified 3 cm lateral to the midline. A 50-80 mm needle was inserted in a cranio-caudal direction using either in-plane or out-of-plane technique until contact with the transverse process. Correct needle tip position was confirmed by visualizing linear spread of 1 mL normal saline between the erector spinae muscle and transverse process. After negative aspiration, 20 mL of 0.25% bupivacaine was injected (not exceeding 3 mg/kg total dose). The procedure was repeated on the contralateral side.

Hypotension (defined as systolic blood pressure <80% of baseline or <90 mmHg) was treated with IV crystalloid boluses and phenylephrine 100 µg or ephedrine 6 mg as needed. Nausea and vomiting were treated with ondansetron 4 mg IV. Oxytocin 10 IU over 10 minutes followed by 15 IU over 10 minutes was administered for uterine tone maintenance.

Postoperative Analgesia Protocol

Both groups received identical multimodal non-opioid analgesia as rescue medication:

In PACU (Post-Anesthesia Care Unit):

- Paracetamol 1 g IV + Ketoprofen 100 mg IM (systematic)
- If VAS >4: Nefopam 20 mg IV over 30 minutes and/or Tramadol 1 mg/kg IV
- If VAS remained >4 despite nefopam and tramadol: Morphine IV titration

From H2 to H24:

- Paracetamol 1 g IV three times daily (if pain present)
- Ketoprofen 100 mg IM twice daily (systematic)
- If VAS >4: Nefopam 40 mg three times daily
- If VAS >4 despite nefopam: Tramadol 100 mg PO twice daily or Morphine 5 mg SC twice daily

Importante note: In practice, the ESP group rarely required opioid rescue analgesia, achieving predominantly opioid-free postoperative pain management.

ERAS Protocol Components

All patients followed a comprehensive ERAS pathway including:[29,30]

- Urinary catheter removal at H2 (PACU discharge)
- IV line capped at H2 (after oxytocin infusion completion)
- Oral fluid intake encouraged from PACU discharge
- Light diet from H4 (yogurt, compote, bread, soup)
- Unrestricted diet from H8
- First mobilization encouraged at H6
- Early breastfeeding initiation
- Thromboprophylaxis with low molecular weight heparin 6-12 hours post-surgery (unless contraindicated)

Outcome Measures

Primary Outcome

Time to first analgesic request (hours), defined as the interval from ESP block completion or intrathecal morphine injection to first administration of rescue analgesia.

Secondary Outcomes

1. **Pain intensity:** Visual Analog Scale (VAS, 0-10) scores assessed at rest at H2, H4, H6, H8, H16, H20, and H24; and during movement at H6, H8, H16, H20, and H24
2. **Analgesic consumption:** Total paracetamol and nefopam consumption at 24 hours; number of doses; timing of administration
3. **Adverse effects:**
   - Postoperative nausea and vomiting (PONV)
   - Pruritus
   - Urinary retention (bladder globe)

- Respiratory depression (respiratory rate <8/min or SpO_2 <92% on room air)
- Gastrointestinal recovery (return of flatus/bowel movements)

4. **Maternal satisfaction:** Assessed at 24 hours using a 4-point scale (very satisfied, satisfied, somewhat satisfied, dissatisfied)

5. **Hospital length of stay** (hours from surgery to discharge)

6. **ERAS compliance:** Achievement of mobilization at H6, oral intake at H2, light diet at H4, unrestricted diet at H8

Statistical Analysis

Statistical analyses were performed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA). Continuous variables were tested for normality using the Shapiro-Wilk test. Normally distributed continuous data are presented as mean ± standard deviation and compared using independent samples t-tests. Non-normally distributed data are presented as median [interquartile range] and compared using Mann-Whitney U tests. Categorical variables are presented as frequencies and percentages and compared using chi-square tests or Fisher's exact test as appropriate.

Survival analysis for time to first analgesic request was performed using Kaplan-Meier curves with log-rank test for group comparisons. Patients who did not require rescue analgesia were censored at 24 hours.

Multivariate linear regression was used to identify independent predictors of time to first analgesic request, adjusting for potential confounders including maternal age (≥32 vs <32 years), body mass index (BMI ≥30 vs <30 kg/m²), parity (≥1 vs nulliparous), gestational age (≥39 vs <39 weeks), gravidity (≥3 vs <3), and number of previous cesareans (≥3 vs <3).

Multivariate logistic regression was employed to identify factors associated with adverse effects and VAS ≥4 at different time points, reporting adjusted odds ratios (OR) with 95% confidence intervals (CI).

All tests were two-tailed with statistical significance set at $p<0.05$. Given multiple comparisons, Bonferroni correction was applied where appropriate.

RESULTS

Patient Flow and Baseline Characteristics

Between February 2023 and December 2024, 2,304 elective cesarean deliveries were performed at our institution. Of these, 140 patients met eligibility criteria and were enrolled: 70 in the Morphine group and 70 in the ESP block group. All patients completed the study protocol with no dropouts or protocol violations (Figure 1).

Baseline demographic and obstetric characteristics were well-balanced between groups (Table 1). Mean maternal age was 31.6±4.2 years in the Morphine group versus 32.3±4.5 years in the ESP group ($p=0.325$). Mean BMI was 30.2±4.4 kg/m² versus 31.4±5.3 kg/m² ($p=0.159$). The majority of patients in both groups were aged 30-39 years (62.9% vs 57.2%) and nulliparous (71.4% vs 81.4%, $p=0.120$). Gestational age was comparable (39.1±1.1 vs 38.8±1.0 weeks, $p=0.159$).

The most common indication for cesarean delivery in both groups was previous uterine scar (34.3% vs 40.0%, $p=0.48$). Patients with ≥3 previous cesareans were more frequent in the ESP group (20.0% vs 10.0%, $p=0.04$), while cephalopelvic disproportion was more common in the Morphine group (17.1% vs 2.9%, $p=0.005$). History of infertility was more prevalent in the ESP group (17.1% vs 5.7%, $p=0.034$).

Table 1: Baseline Demographic and Obstetric Characteristics

Characteristic	Morphine (n=70)	ESP Block (n=70)	p-value
Age (years), mean ± SD	31.6 ± 4.2	32.3 ± 4.5	0.325
BMI (kg/m²), mean ± SD	30.2 ± 4.4	31.4 ± 5.3	0.159
Nulliparous, n (%)	50 (71.4)	57 (81.4)	0.120
Parity, mean ± SD	0.78 ± 1.55	0.38 ± 1.05	0.070
Gestational age (weeks), mean ± SD	39.1 ± 1.1	38.8 ± 1.0	0.159
≥3 previous cesareans, n (%)	7 (10.0)	14 (20.0)	0.040
Previous uterine scar, n (%)	24 (34.3)	28 (40.0)	0.480

Primary Outcome: Time to First Analgesic Request

The ESP block group demonstrated significantly prolonged analgesia compared to the Morphine group. The median time to first analgesic request was 16 hours (IQR: 8-24) in the ESP group versus 6 hours (IQR: 6-8) in the Morphine group ($p<10^{-17}$). Mean time to first request was 16.88±5.09 hours in the ESP group versus 6.86±3.43 hours in the Morphine group (mean difference: 10.02 hours, 95% CI: 8.54-11.50, $p<10^{-17}$) (Table 2, Figure 2).

Kaplan-Meier survival analysis revealed distinct separation of curves from the earliest time points, with significantly higher proportions of ESP patients remaining analgesic-free throughout the 24-hour observation period (log-rank $p<0.001$) (Figure 3).

At rest, median time to first analgesic request was 16 hours (mean 17.02±4.52 hours) in the ESP group versus 8 hours (mean 8.49±5.45 hours) in the Morphine group ($p<10^{-6}$). Notably, 38.6% of ESP patients required no analgesics at rest within 24 hours, compared to 0% in the Morphine group ($p<10^{-6}$).

During movement, median time to first analgesic request was 16 hours (mean 17.95±6.22 hours) in the ESP group versus 16 hours (mean 14.89±7.48 hours) in the Morphine group (p=0.033). While the difference was smaller than at rest, 42.9% of ESP patients required no analgesics during movement versus 10.0% of Morphine patients ($p<10^{-6}$).

Table 2: Primary and Key Secondary Outcomes

Outcome	Morphine (n=70)	ESP Block (n=70)	p-value
Primary outcome			
Time to first analgesic (h), median [IQR]	6 [6-8]	16 [8-24]	$<10^{-17}$
Time to first analgesic (h), mean ± SD	6.86 ± 3.43	16.88 ± 5.09	$<10^{-17}$
No analgesic required at 24h, n (%)	0 (0)	27 (38.6)	$<10^{-6}$
Pain scores at rest			
VAS H2, mean ± SD	1.24 ± 1.78	0.00 ± 0.00	0.001
VAS H8, mean ± SD	1.97 ± 1.47	0.58 ± 0.87	0.004
VAS H24, mean ± SD	1.61 ± 1.56	0.61 ± 1.15	0.001
Pain scores during movement			
VAS H6, mean ± SD	1.89 ± 1.92	0.78 ± 1.19	0.011
VAS H24, mean ± SD	1.96 ± 1.74	1.49 ± 1.10	0.021
Analgesic consumption (24h)			
Paracetamol (mg), mean ± SD	1310.8 ± -	601.6 ± -	<0.001
Nefopam (mg), mean ± SD	9.42 ± -	1.72 ± -	<0.001

Secondary Outcomes
Pain Intensity

At rest: VAS scores were consistently and significantly lower in the ESP group at multiple time points. At H2, mean VAS was 0.00±0.00 in the ESP group versus 1.24±1.78 in the Morphine group (p=0.001). This superiority persisted at H4 (0.07±0.35 vs 0.95±1.57, p=0.003), H6 (0.47±1.19 vs 1.34±1.98, p=0.012), H8 (0.58±0.87 vs 1.97±1.47, p=0.004), and H24 (0.61±1.15 vs 1.61±1.56, p=0.001). At H16 and H20, differences were not statistically significant (p=0.210 and p=0.361, respectively) (Figure 4A).

Categorical analysis revealed that 100% of ESP patients had VAS <3 at H2, H4, and H6, compared to 87.1%, 91.4%, and 82.9% respectively in the Morphine group (all p<0.05). At H8, all ESP patients maintained VAS <4, while 58.6% of Morphine patients had VAS 3-5 ($p<10^{-6}$).

During movement:

VAS scores during mobilization were significantly lower in the ESP group at H6 (0.78±1.19 vs 1.89±1.92, p=0.011), H8 (1.44±0.86 vs 0.98±1.20, p=0.030), and H24 (1.49±1.10 vs 1.96±1.74, p=0.021). No significant differences were observed at H16 and H20 (p=0.161 and p=0.371, respectively) (Figure 4B).

At H6 during movement, 95.7% of ESP patients had VAS <3 compared to 78.6% of Morphine patients (p=0.021). At H24, these proportions were 75.7% versus 50.0% (p=0.010).

Rescue Analgesic Consumption

Total analgesic consumption was significantly lower in the ESP group. Mean paracetamol consumption was 601.6 mg in the ESP group versus 1310.8 mg in the Morphine group (p<0.001), representing a 54% reduction. Mean nefopam consumption was 1.72 mg versus 9.42 mg (p<0.001), an 82% reduction.

At rest, 94.3% of Morphine patients required paracetamol compared to 55.7% of ESP patients ($p<10^{-6}$). Multi-dose paracetamol was needed in 40.9% of Morphine patients versus only 7.7% of ESP patients (p=0.000006). Similarly, nefopam was required in 47.1% of Morphine patients versus 8.6% of ESP patients (p=0.000004).

During movement, paracetamol consumption was lower in the ESP group (51.4% vs 67.1%, p=0.058), with no ESP patient requiring multiple doses compared to 23.4% in the Morphine group (p=0.00002). Nefopam use during movement was 5.7% in the ESP group versus 31.4% in the Morphine group (p=0.0002).

Adverse Effects

The ESP block demonstrated a markedly superior safety profile across all opioid-related adverse effects (Table 3).

Postoperative nausea and vomiting (PONV):

Incidence was 22.9% in the ESP group versus 65.7% in the Morphine group (p<0.001), representing a 65% relative risk reduction. Multivariate analysis revealed adjusted odds ratios ranging from 3.5 to 15.0

across demographic subgroups, all statistically significant (p<0.001).

Pruritus:

Incidence was dramatically lower in the ESP group: 17.1% versus 81.4% (p<0.001), a 79% relative risk reduction. Adjusted odds ratios ranged from 20 to 70 in multivariate analysis (all p<0.001), confirming this as a morphine-specific complication virtually absent with ESP block.

Urinary retention (bladder globe):

Occurred in 14.3% of Morphine patients but 0% of ESP patients (p=0.003). Multivariate analysis identified obesity (BMI ≥30), gravidity ≥3, and gestational age <39 weeks as independent risk factors in the Morphine group (all OR >2, p<0.05).

Respiratory depression:

No cases occurred in either group, confirming the safety of both techniques when used with appropriate monitoring.

Gastrointestinal recovery: Return of bowel function by 24 hours was similar between groups (71.4% vs 72.9%, p=0.85).

Table 3. Adverse Effects Profile

Adverse Effect	Morphine (n=70)	ESP Block (n=70)	p-value	RRR (%)
PONV, n (%)	46 (65.7)	16 (22.9)	<0.001	65
Pruritus, n (%)	57 (81.4)	12 (17.1)	<0.001	79
Urinary retention, n (%)	10 (14.3)	0 (0)	0.003	100
Respiratory depression, n (%)	0 (0)	0 (0)	NS	-
Bowel function return at 24h, n (%)	50 (71.4)	51 (72.9)	0.850	-

RRR = relative risk reduction; PONV = postoperative nausea and vomiting; NS = not significant

Maternal Satisfaction

Maternal satisfaction was significantly higher in the ESP group (p=0.014). The proportion of "very satisfied" patients was 84.3% in the ESP group versus 62.9% in the Morphine group. Overall satisfaction (very satisfied + satisfied) was 97.1% versus 91.4%. Conversely, 10.0% of Morphine patients reported being "not very satisfied" or "dissatisfied" compared to only 2.9% in the ESP group.

Hospital Length of Stay

Mean hospital stay was significantly shorter in the ESP group: 26.74±5.84 hours versus 29.31±8.08 hours in the Morphine group (mean difference: 2.57 hours, p=0.03). The proportion of patients discharged at 24 hours was significantly higher with ESP block: 80.0% versus 65.7% (p=0.041).

Multivariate analysis identified gravidity <3 (adjusted OR=0.16, 95% CI: 0.05-0.58, p=0.003) and nulliparity (adjusted OR=0.33, 95% CI: 0.14-0.78, p=0.010) as independent predictors of 24-hour discharge in the ESP group, while analgesic technique itself did not reach independent significance after adjustment for pain control and adverse effects.

ERAS Compliance

Achievement of ERAS milestones was uniformly excellent in both groups, with no significant differences for most components: urinary catheter removal at H2 (100% vs 100%), IV line capping at H2 (100% vs 100%), oral fluids at H2 (100% vs 100%), light diet at H4 (100% vs 100%), and unrestricted diet at H8 (100% vs 100%).

The only significant difference was mobilization at H6: 100% in the Morphine group versus 92.9% in the ESP group (p=0.029), likely reflecting the slightly prolonged motor block duration in some ESP patients, though this did not translate into delayed discharge.

Multivariate Analyses

Predictors of Time to First Analgesic Request

In multivariate linear regression adjusting for age, BMI, parity, gravidity, gestational age, and previous cesareans, analgesic technique emerged as the only independent predictor of time to first analgesic request overall. ESP block prolonged time to first request by 9.4 hours (95% CI: 7.8-11.1, p<0.001) compared to intrathecal morphine, independent of all maternal and obstetric characteristics.

At rest:

In the Morphine group, parity ≥1 was the only independent predictor, prolonging time to first request by 4.5 hours (95% CI: 0.8-8.1, p=0.019). In the ESP group, no demographic or obstetric factors independently influenced analgesic duration at rest (all p>0.05).

During movement:

In the Morphine group, gravidity ≥3 prolonged time to first request (+5.4 hours, p=0.045), while parity ≥1 (-6.9 hours, p=0.014) and ≥3 previous cesareans (-11.0 hours, p=0.003) shortened it. In the ESP group, BM

I ≥30 kg/m² (+5.3 hours, p=0.036) and ≥3 previous cesareans (+7.6 hours, p=0.036) were independently associated with prolonged analgesia during movement.

Predictors of Analgesic Requirements

Multivariate logistic regression revealed that ESP block consistently reduced the odds of requiring rescue analgesia across all maternal subgroups.

At rest:

Adjusted odds ratios for analgesic requirement ranged from 0.29 to 0.40 across age, BMI, gravidity, parity, and gestational age categories (all $p<0.01$), indicating 60-71% odds reduction with ESP block.

During movement:

Adjusted ORs ranged from 0.11 to 0.21 (all $p\leq0.001$ except parity $p=0.060$), representing 79-89% odds reduction.

Notably, 100% of Morphine patients required analgesics at rest within 24 hours, while 38.6% of ESP patients remained analgesic-free ($p<10^{-6}$). During movement, 90.0% of Morphine patients required analgesia versus 57.1% of ESP patients ($p<10^{-6}$).

Predictors of Pain Control (VAS <4)

Multivariate analysis at H8, H16, and H24 revealed temporal patterns of superior pain control with ESP block:

At H8 (rest): No factors reached independent significance, though all ESP subgroups had 100% VAS <4 compared to 86-96% in Morphine subgroups.

At H16 (rest): Age ≥32 years (OR=0.46, p=0.025), BMI ≥30 (OR=0.49, p=0.019), and gestational age ≥39 weeks (OR=0.47, p=0.002) independently predicted VAS <4 in the ESP group.

At H24 (movement):

ESP block technique itself (OR=0.46, p=0.013), along with age ≥32 (OR=0.46, p=0.025), BMI ≥30 (OR=0.49, p=0.019), gravidity ≥3 (OR=0.46, p=0.026), and gestational age ≥39 weeks (OR=0.47, p=0.002) independently predicted optimal pain control.

These findings demonstrate that ESP block provides consistent analgesic benefit across diverse patient profiles, with enhanced effectiveness in certain higher-risk subgroups.

DISCUSSION

This randomized controlled trial demonstrates that bilateral ESP block provides superior post-cesarean analgesia compared to intrathecal morphine when integrated into a comprehensive ERAS protocol. The ESP group achieved significantly prolonged time to first analgesic request (16.88 vs 6.86 hours), reduced rescue analgesic consumption, markedly lower incidence of opioid-related adverse effects, higher maternal satisfaction, and shorter hospital stay. Multivariate analyses confirmed that analgesic technique was the predominant independent predictor of these outcomes, with ESP block offering benefits across diverse maternal and obstetric profiles.

Principal Findings in Context

Our primary outcome—median time to first analgesic request of 16 hours with ESP block versus 6 hours with intrathecal morphine—represents one of the longest durations reported for ESP block in the cesarean literature. This compare favorably with Hamed *et al.,*(12 vs 4.93 hours),[31] and exceeds durations reported by Akdag et al.[32] and Sirin et al.[33] The prolonged effect in our study likely reflects several factors: bilateral block coverage, standardized technique with ultrasound guidance ensuring consistent local anesthetic deposition, higher volume (40 mL total) providing extensive dermatomal spread, and truly opioid-sparing rescue analgesia avoiding confounding effects of systemic opioids.

Notably, 38.6% of ESP patients required no analgesics at rest and 42.9% required none during movement within 24 hours—a finding not reported in prior studies and highlighting the potential for complete opioid-free post-cesarean recovery in a substantial proportion of patients.

Pain Intensity and Dynamic Assessment

The temporal pattern of pain scores revealed ESP block's superiority was most pronounced during the critical early postoperative period (H2-H8) and late period (H24), with convergence at H16-H20. This biphasic pattern may reflect the pharmacokinetics of intrathecal morphine (early onset with peak effect around H4-H8) versus the sustained steady-state provided by ESP block. The resurgence of ESP superiority at H24 suggests morphine's effect wanes as ESP block maintains coverage, consistent with the 18-24 hour duration of 0.25% bupivacaine in fascial planes.[34]

Our differentiated assessment of pain at rest versus during movement—a methodologic strength rarely employed—revealed clinically important distinctions. While both techniques provided acceptable analgesia at rest, ESP block demonstrated clear superiority during movement (H6, H8, H24), the most functionally relevant assessment for ERAS protocols prioritizing early mobilization.[35,36] This finding has direct implications for pathway implementation and likely contributed to the higher ERAS compliance and earlier discharge observed.

Opioid-Related Adverse Effects

The dramatic reduction in opioid-related complications represents perhaps the most clinically significant finding. PONV incidence of 22.9% with ESP versus 65.7% with morphine, pruritus 17.1% versus 81.4%, and urinary retention 0% versus 14.3% translate to number-needed-to-treat (NNT) values of 2.3, 1.6, and 7.0 respectively—clinically meaningful reductions that directly impact maternal comfort, ERAS compliance, and resource utilization.[37]

These findings align with those of Sirin *et al.,*(PONV 5% vs 30%, pruritus 0% vs 25%),[33] Hamed *et al.,*[31] and the recent meta-analysis by Hussain *et al.,*[38] but with larger effect sizes likely attributable to complete morphine exclusion in our ESP group versus partial opioid reduction in prior studies. The complete

absence of urinary retention in the ESP group facilitated early catheter removal and spontaneous voiding, key ERAS targets often complicated by neuraxial opioids.[39]

Importantly, no respiratory depression occurred in either group, confirming the safety of intrathecal morphine 100 μg when appropriately monitored, while demonstrating that ESP block's comparable analgesia comes without this rare but serious risk.[40]

Maternal Satisfaction and Patient-Centered Outcomes

The 84.3% rate of "very satisfied" patients in the ESP group versus 62.9% with morphine (p=0.014) reflects the cumulative impact of superior pain control, fewer adverse effects, earlier mobilization, and enhanced recovery experience. This patient-centered outcome is increasingly recognized as a key quality metric in obstetric anesthesia[41] and strongly correlates with successful ERAS pathway implementation.[42]

Our use of a four-point satisfaction scale provided greater discrimination than the three-point scales employed in some prior studies,[31] capturing nuanced differences in maternal experience. The convergence of objective (pain scores, adverse effects) and subjective (satisfaction) outcomes strengthens confidence in ESP block's overall superiority from the patient perspective.

Hospital Stay and Health Economics

The 2.57-hour reduction in mean hospital stay (p=0.03) and 14.3% absolute increase in 24-hour discharge rate translate to significant operational and economic benefits. Our projected cost savings of 2.9 million Algerian dinars per month (approximately 60% cost reduction per patient) make ESP block particularly attractive for resource-limited settings.[43]

This finding extends beyond individual patient benefit to healthcare system efficiency. With global cesarean rates exceeding 20 million annually,[2] even modest per-patient savings compound to substantial system-level impact. The economic case for ESP block is further strengthened by considering indirect costs: reduced nursing time for adverse effect management, decreased medication administration, and avoidance of extended monitoring requirements for neuraxial opioid respiratory depression surveillance.[44]

Multivariate Analyses: Personalized Medicine Insights

Our comprehensive multivariate analyses provided novel insights for personalized analgesia. While analgesic technique dominated as the primary determinant of outcomes, subgroup analyses revealed important nuances:

Parity emerged as a modifier in the morphine group, with multiparous women experiencing longer analgesic duration at rest (+4.5 hours, p=0.019), possibly reflecting altered pain perception or tolerance from prior experience. Conversely, during movement, multiparity and multiple previous cesareans predicted *shorter* analgesic duration, potentially due to adhesions or altered tissue planes affecting nociceptive pathways.[45]

BMI ≥30 kg/m² and ≥3 previous cesareans independently predicted prolonged analgesia during movement in the ESP group (+5.3 and +7.6 hours respectively), suggesting enhanced benefit in these higher-risk populations. This aligns with ESP block's ability to provide consistent fascial plane coverage regardless of body habitus or surgical history, unlike neuraxial techniques where anatomy may be distorted.[46]

Age ≥32 years and gestational age ≥39 weeks independently predicted better pain control at H16 and H24 (all OR <0.5, p<0.05), though the mechanisms remain speculative. These may relate to physiologic or hormonal factors influencing pain processing in older mothers or at term.[47]

Critically, no maternal or obstetric factor eliminated ESP block's advantage, confirming its effectiveness across the full spectrum of cesarean patients—a key consideration for protocol standardization.

Technical Considerations

ESP block performance time, though not a primary outcome, averaged 4.30±0.52 minutes in patients with BMI <25 kg/m² versus 6.70±0.76 minutes in those with BMI ≥25 ($p<10^{-23}$), remaining clinically acceptable even in obese patients. This compares favorably with more technically demanding blocks like transversus abdominis plane (TAP) or quadratus lumborum (QL) blocks.[48]

All blocks were performed successfully without complications, confirming ESP block's favorable safety profile. The superficial anatomic landmarks (transverse processes easily identifiable with ultrasound), compressible structures allowing "feel" for needle depth, and distance from neuraxial and vascular structures contribute to its learning curve advantages.[49,50]

Comparison with Alternative Regional Techniques

Our results compare favorably with the extensive literature on TAP and QL blocks for post-cesarean analgesia. While TAP block provides effective somatic analgesia,[51] it lacks visceral coverage, potentially explaining its frequent inferiority to neuraxial morphine in comparative trials.[52] QL block offers

theoretical advantages with visceral spread,[53] though evidence of clinical superiority over TAP remains inconsistent.[54]

ESP block's proposed mechanisms—paravertebral spread via epidural and intervertebral foraminal routes, providing both somatic and visceral coverage[18-20]—may explain its consistent performance. Recent anatomical studies demonstrate ESP injectate reaches paravertebral space in 80-100% of cases,[55] supporting its ability to block both anterior and posterior rami, unlike pure fascial plane blocks confined to anterior abdominal wall.

The recent network meta-analysis by Hussain *et al.,* including 73 trials and 5,847 patients found ESP block non-inferior to intrathecal morphine for pain scores but with significantly fewer adverse effects,[38] consistent with our findings. Our study adds to this evidence base with robust sample size, comprehensive multivariate analyses, and complete opioid exclusion design.

Integration with ERAS Principles

ERAS pathways for cesarean delivery emphasize multimodal opioid-sparing analgesia, early mobilization, rapid return to oral intake, and minimization of lines/tubes.[9,10,27,28] ESP block proved ideally suited to these goals: providing prolonged analgesia without motor block (facilitating H6 mobilization in 92.9% of patients), eliminating most opioid-related adverse effects that impede oral intake, and requiring no catheter maintenance or patient-controlled analgesia equipment.

The 100% achievement of dietary milestones (fluids at H2, light diet at H4, unrestricted diet at H8) in both groups demonstrates successful ERAS implementation, with ESP block's lower PONV incidence (22.9% vs 65.7%) directly supporting these nutritional goals. The urinary catheter removal at H2 (100% compliance) and absence of urinary retention in the ESP group exemplifies ERAS-friendly care.

These pathway-level benefits likely contributed to the observed hospital stay reduction and may have additional unmeasured effects on patient autonomy, confidence, and breastfeeding success—outcomes deserving of future investigation.

Implications for Practice

Based on these findings, we propose bilateral ESP block be considered the regional technique of choice for post-cesarean analgesia within ERAS protocols, particularly for:

- Patients at high risk for opioid adverse effects (young age, history of PONV, obesity)
- Those requiring rapid return to function (primiparous mothers, early discharge candidates)
- Settings emphasizing opioid-sparing strategies
- Institutions with ultrasound-guided regional anesthesia capability

Intrathecal morphine remains a valuable option when ESP block expertise is unavailable, patient factors favor neuraxial approaches (e.g., high gravidity without parity based on our predictive models), or logistic constraints preclude ultrasound-guided techniques. However, the dramatic reduction in adverse effects, improved patient experience, and operational benefits we demonstrated argue strongly for institutional investment in ESP block education and implementation.

Strengths and Limitations

Strengths:

This study's strengths include adequate sample size with robust statistical power, prospective randomized design minimizing selection bias, comprehensive outcome assessment including patient-centered metrics, rigorous multivariate analyses identifying independent outcome predictors, complete integration within a standardized ERAS protocol, and truly opioid-free rescue analgesia in the ESP group—a unique methodologic feature allowing unconfounded efficacy assessment.

Limitations:

Single-center design limits generalizability, though our population's diverse characteristics (including high proportions of obesity, multiparity, and previous cesareans) enhance external validity. Single-blind design (impossible to blind anesthesiologists) introduces potential performance bias, partially mitigated by blinded outcome assessment. Follow-up limited to 24 hours precludes assessment of chronic post-surgical pain, an important long-term outcome.[56] Lack of cost-utility analysis and quality-adjusted life-year calculations limit economic conclusions.

We did not measure plasma local anesthetic levels, though no signs of local anesthetic systemic toxicity occurred. Standardization to T9 level may not be optimal for all patients; some authors advocate higher (T7-T8) or lower (T10) injection sites,[57] though evidence guiding level selection remains limited.

Future Research Directions

This trial generates several research imperatives: **(1)** Multicenter validation in diverse settings and populations; **(2)** Long-term follow-up assessing chronic post-cesarean pain, a complication affecting 10-20% of women;[58] **(3)** Cost-effectiveness analyses from healthcare system and societal perspectives; **(4)** Optimal dosing studies exploring volume, concentration, and adjuvant effects; **(5)** Comparative effectiveness research versus QL block and continuous ESP catheter techniques; **(6)** Investigation of ESP block's impact on breastfeeding success and maternal-infant bonding; **(7)** Implementation science

studies assessing barriers and facilitators to ESP block adoption in diverse practice environments; and **(8)** Development and validation of prediction models identifying patients most likely to benefit from specific analgesic techniques.

CONCLUSIONS

Bilateral erector spinae plane block provides superior post-cesarean analgesia compared to intrathecal morphine when integrated into an enhanced recovery protocol. ESP block prolonged time to first analgesic request by approximately 10 hours, reduced pain scores at rest and during mobilization, dramatically decreased opioid-related adverse effects including PONV (65% reduction), pruritus (79% reduction), and urinary retention (eliminated), enhanced maternal satisfaction, and shortened hospital stay. These benefits were consistent across diverse maternal and obstetric characteristics, with ESP block emerging as the predominant independent predictor of favorable outcomes in multivariate analysis.

Our findings support bilateral ESP block as a cornerstone regional anesthetic technique for post-cesarean ERAS pathways, offering effective analgesia with an excellent safety profile and facilitating the rapid return to function central to enhanced recovery principles. The substantial reduction in morphine-related complications addresses a major barrier to optimal ERAS implementation while improving patient experience. For healthcare systems globally—particularly those in resource-limited settings—ESP block represents an opportunity to simultaneously improve clinical outcomes, enhance patient satisfaction, and reduce costs.

We advocate for incorporation of ESP block into institutional protocols for elective cesarean delivery, supported by appropriate education and training programs. Continued research should focus on long-term outcomes, economic evaluation, technique optimization, and identification of patient populations deriving maximal benefit from this promising regional anesthesia approach.

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Author Contributions

AR: Conceptualization, methodology, investigation, data collection, formal analysis, writing—original draft. RA : Conceptualization, methodology, supervision, writing—review and editing, final approval. Both authors have read and approved the final manuscript.

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