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ORIGINAL RESEARCH

Evaluation of ropivacaine in external oblique intercostal block for analgesia in major upper abdominal surgery: a randomized controlled clinical trial

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Abstract

Background: To evaluate the efficacy and safety of bilateral external oblique intercostal (EOI) nerve block using ropivacaine for postoperative analgesia in patients undergoing major upper abdominal laparoscopic surgery. **Methods**: This prospective, randomized controlled trial enrolled patients who were randomly assigned to either the control group or the EOI group using a computer-generated randomization table. The primary outcome was sufentanil consumption via patient-controlled analgesia within 24 hours postoperatively. Pain intensity was assessed using the visual analog scale (VAS). Statistical analyses were performed using *t*-test and the Mann-Whitney U-test to compare analgesic efficacy and safety between the two groups. **Results**: A total of 78 patients were included in the study. Data analysis showed that patients in the EOI group had significantly lower sufentanil consumption at 24 hours postoperatively than those in the control group (median: 52 μg (50–54) *vs.* 54 μg (52–54); difference in medians with 95% confidence interval (CI): 0.000 to 2.000, $p = 0.027$, Mann-Whitney U-test with Hodges-Lehmann estimate). At 1 hour post-surgery, the control group had a significantly higher VAS score for incision pain compared to the EOI group (median: 2 (1–4) *vs.* 1 (0–2), $p = 0.005$). Additionally, tramadol consumption was significantly higher in the control group than in the EOI group at 1 hour postoperatively (median: 0 (0–50) *vs.* 0 (0–0), $p = 0.038$). No significant differences were observed in other secondary outcome parameters. **Conclusions**: EOI nerve block with ropivacaine can effectively reduce postoperative incision pain, minimizes the need for rescue analgesics, and exhibits a favorable safety profile in patients undergoing major upper abdominal laparoscopic surgery. **Chinese Clinical Trial Registry**: ChiCTR2400089685.

Keywords

External oblique intercostal; Nerve block; Postoperative pain; Abdominal surgery; Ropivacaine; Surgical intensive care unit

1. Introduction

Patients undergoing major upper abdominal surgery, particularly those with malignant tumors requiring laparoscopic procedures, face considerable perioperative risks [1], with an increasing demand for surgical intensive care unit (SICU) admissions among those with complex medical histories undergoing abdominal surgery [2]. Many of these patients are elderly and frail, making them more susceptible to adverse postoperative outcomes [3, 4]. Given these challenges, postoperative analgesia management in SICU patients requires particular attention to minimize complications and improve recovery [5].

Previous studies have highlighted the importance of implementing multimodal analgesia as an effective approach for managing postoperative pain following abdominal surgery [6]. Among the available techniques, fascial plane blocks have gained attention due to their efficacy in reducing opioid consumption and improving pain control. The subcostal transversus abdominis plane (TAP) block is commonly used for upper abdominal analgesia; however, its effectiveness in this region remains incomplete [7].

The external oblique intercostal (EOI) plane block has emerged as a promising alternative for postoperative analgesia [8, 9]. Through cadaveric studies, Hesham Elsharkawy *et al.* [10] demonstrated that this technique consistently stained the lateral and anterior branches of the intercostal nerves (T7–T10) and produced long-lasting sensory blockade in the anterior axillary and midline regions, covering dermatomes T6–T10 and T6–T9. Subsequent studies have explored the efficacy of EOI blocks in various abdominal procedures, further supporting their potential role in multimodal analgesia [11–13].

Despite these findings, previous studies primarily utilized bupivacaine rather than ropivacaine for EOI blocks, and no randomized controlled trials have evaluated the effectiveness of this technique in patients undergoing major upper abdominal surgery requiring SICU admission. Herein, we hypothesized that EOI block with ropivacaine would provide safe and effective postoperative analgesia, offering superior pain control compared to conventional multimodal analgesia alone. Based on this, the primary objective of our study was to assess sufentanil consumption via patient-controlled analgesia within 24 hours after tracheal extubation and evaluate the patients' vital signs, pain scores and reported analgesia outcomes as secondary outcomes.

2. Materials and methods

2.1 Study design and ethics

This prospective, randomized controlled trial was approved by the Ethics Committee of Jiaxing First Hospital (approval number: 2024-LY-673) and conducted at the Department of Anesthesiology between 12 September and 25 October 2024. Written informed consent was obtained from all participants, and the study did not include minors. The trial was registered in the Chinese Clinical Trial Registry (www.chictr.org.cn; trial number: ChiCTR2400089685). All procedures adhered to the principles of the Declaration of Helsinki and followed the reporting standards outlined in the Consolidated Standards of Reporting Trials (CONSORT) guidelines.

2.2 Participants

A total of 78 patients aged 18–75 years scheduled for elective laparoscopic upper abdominal surgery were selected for this study. Patients were considered eligible if they had an American Society of Anesthesiologists (ASA) physical status classification of II–III and were to be admitted to the SICU postoperatively. They were stratified based on the type of upper abdominal surgery, including gastrectomy, hepatectomy and pancreatectomy. Exclusion criteria included known allergies to local anesthesia, severe coagulopathy, infection at the puncture site, significant cardiopulmonary disease or kidney dysfunction, a history of chronic pain or long-term analgesic use, and inability to comply with postoperative follow-up. All patients provided written and verbal consent before participation.

2.3 Randomization and blinding

The participants were randomly assigned to the control or EOI group using a computer-generated randomization table. Group assignments were concealed in sealed envelopes, which were opened by the anesthesiologist responsible for anesthesia induction upon the patient's arrival in the operating room. Based on the assigned group, the anesthesiologist determined whether to perform an EOI block before surgery or not. To ensure blinding, an investigator who was unaware of group assignments did not enter the operating room until after surgery. While the anesthesiologist was aware of the patient's allocation, the patients, outcome assessors, and data analysts remained blinded to group assignments.

2.4 Procedures

Upon entering the operating room, patients were monitored using standard anesthesia equipment to continuously record heart rate (HR), pulse oxygen saturation (SpO_2), and respiratory rate (RR). Mean arterial pressure (MAP) was measured via radial artery puncture. Preoxygenation was administered before anesthesia induction, which included intravenous atropine (0.01 mg/kg), propofol (2 mg/kg), rocuronium (0.6 mg/kg), and sufentanil (0.3 μg/kg). Following induction, tracheal intubation was performed after three minutes of mask ventilation.

During surgery, anesthesia was maintained with remifentanil, administered at a rate of 0.01–0.2 μg/kg/min, and sevoflurane, adjusted to a minimum alveolar concentration of 0.8–1. MAP was maintained within 20% of baseline, and electroencephalographic (EEG) dual monitoring was used to ensure a frequency range of 40–60. Mechanical ventilation was delivered in volume-controlled mode with a tidal volume of 6–8 mL/kg, ensuring an end-tidal carbon dioxide concentration of 35–45 mmHg. Muscle relaxation was sustained with intermittent boluses of cisatracurium (0.03 mg/kg).

The number of surgical incisions and drainage tubes was recorded at the end of surgery. Extubation was performed once the patient met the extubation criteria. Before emergence from anesthesia, 4 mg of ondansetron and 0.1 mg/kg of nalbuphine were administered. Postoperatively, all patients received intravenous patient-controlled analgesia (IV-PCA), prepared with sufentanil (1.5 μg/kg) and ondansetron (8 mg) in 0.9% normal saline, totaling 100 mL. The IV-PCA device (REHN(M01), Rehn Med Tech Ltd., Taizhou, Jiangsu, China) was connected at the end of surgery and programmed with a demand dose of 2 mL, a 20-minute lockout interval, and a continuous background infusion of 2 mL/h. Then, the patients were transferred to the SICU for postoperative management.

For the study group, the EOI block was performed by the same anesthesiologist before anesthesia induction. Ultrasound guidance (SC6-1U/Resona7, Mindray, Shenzhen, Guangdong, China) was used to visualize the intercostal muscles, external oblique muscle, and subcutaneous tissue in a sagittal plane at the level of the sixth rib, between the anterior axillary and midclavicular lines (Fig. 1). The injection site was identified as the fascial plane between the external oblique and intercostal muscles. Using an in-plane technique, a 22 G, 80 mm block needle (Stimuplex B-Braun Medical, Melsungen, HE, Germany) was inserted, and 20 mL of 0.375% ropivacaine was administered bilaterally.

In the SICU, patients were assessed while awake at 1, 4, 8 and 24 hours after extubation, and relevant clinical data were recorded. Pain intensity was evaluated using the visual analog scale (VAS), where 0 represented no pain and 10 indicated the worst possible pain. If a patient reported a VAS score of $\geq$4 at rest, intravenous tramadol (50 mg) was administered. Pain was reassessed after 30 minutes, and if the VAS score remained $\geq$4, an additional 50 mg dose of tramadol was given. If the patient continued to experience pain, further

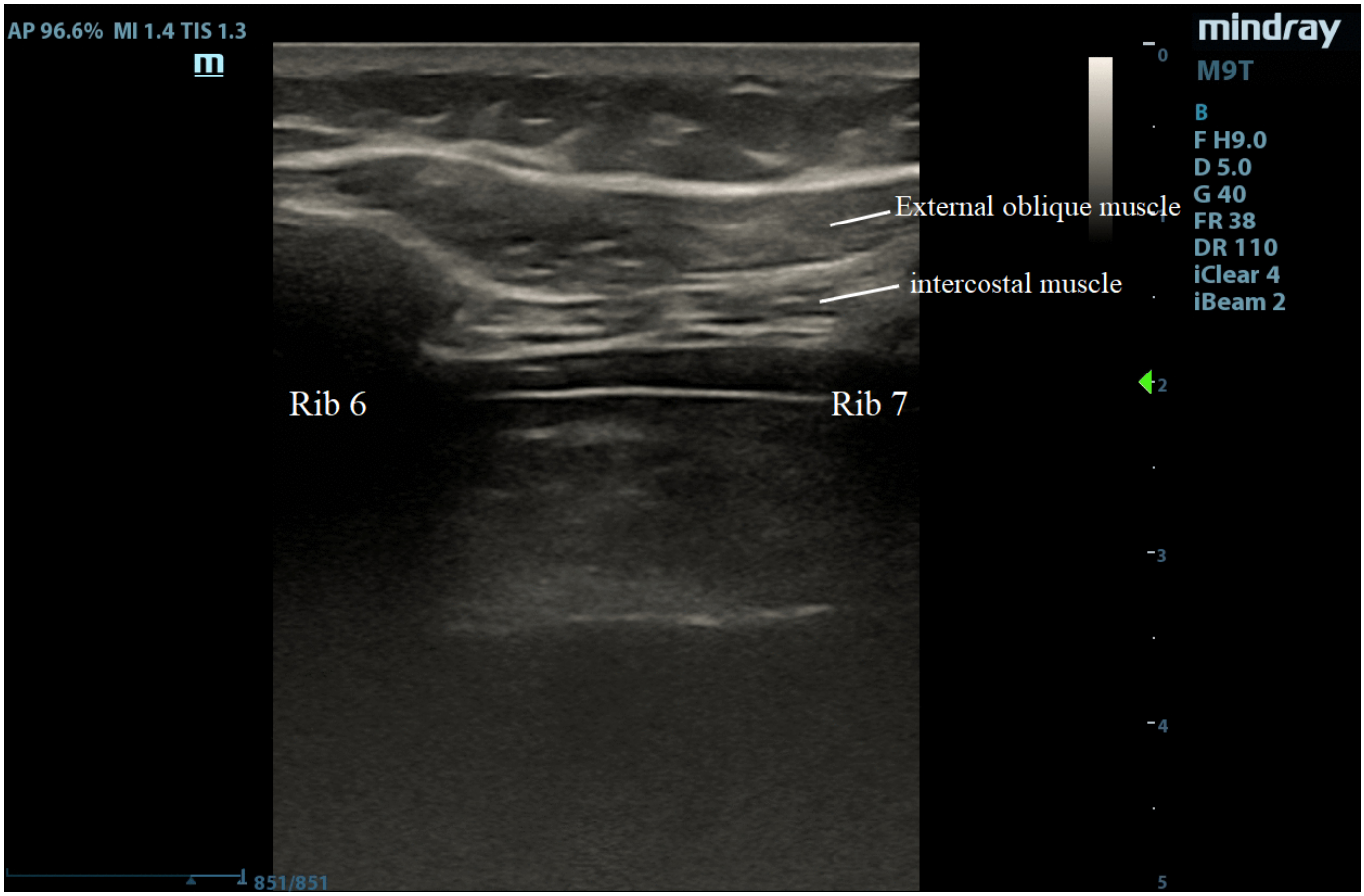

FIGURE 1. Ultrasound-guided visualization of the external oblique intercostal block.

reassessment was conducted. Patients with persistent VAS scores of ≥4 despite tramadol administration were given 25 mg of intravenous pethidine as a rescue analgesic.

The quality of postoperative recovery was assessed using the 15-item Quality of Recovery (QoR-15) scale, cognitive function was evaluated with the Mini-Mental State Examination (MMSE), and anxiety levels were measured using the Self-Rating Anxiety Scale (SAS) [14–16]. Complications related to the nerve block were systematically recorded. Puncture site hemorrhage was noted if present during the procedure. Postoperative inflammatory signs, including local redness, swelling, heat, pain or exudation at the block site, were classified as local infections. Local swelling, pain and skin discoloration were indicative of hematoma formation. Persistent skin numbness or tingling was categorized as nerve injury, while rash or respiratory distress was considered an allergic reaction.

2.5 Outcomes

The primary outcome of this study was sufentanil consumption via the analgesic pump at 24 hours post-extubation. Secondary outcomes included blood pressure, HR, SpO_2, VAS scores, rescue analgesic consumption, the QoR-15 score, the SAS score, the Mini-Mental State Examination (MMSE) score, and the incidence of complications.

2.6 Statistical analysis

A pilot study involving eight patients per group was conducted to determine the required sample size. The mean sufentanil consumption 24 hours postoperatively was 53.5 ± 1.91 μg in the control group and 52 ± 1.63 μg in the EOI group. Based on a statistical power of 80% and an α level of 0.05, a minimum sample size of 62 patients (31 per group) was calculated using PASS 2021 software (NCSS Inc, Kaysville, UT, USA). To account for a 20% dropout rate, the final sample size was set at 39 patients per group.

Statistical analyses were performed using SPSS software (version 25; IBM Corporation, Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD) or median (interquartile range (IQR)), and categorical variables were presented as n (%). The normality of continuous variable distributions was assessed using the Shapiro-Wilk W test, and variance equality was evaluated with Levene's test. Parametric data were analyzed using the Student's *t*-test, while nonparametric data were assessed using the Mann-Whitney U-test, with the Hodges-Lehmann estimator used to determine the 95% confidence interval. Categorical variables were compared using either the chi-square test or Fisher's exact test. A *p*-value of < 0.05 was considered statistically significant for all analyses.

3. Results

3.1 Study population

A total of 78 patients were screened for eligibility and randomly assigned to one of two groups. During the study, four patients were excluded from the final analysis due to open surgery (n = 1), failure to be transferred to the SICU (n = 2), or loss to follow-up (n = 1). Consequently, 74 patients met the inclusion criteria and were included in the final analysis (Fig. 2). The demographic and baseline characteristics of the two groups were comparable, with no statistically significant differences ($p > 0.05$) (Table 1).

3.2 Vital signs

The patients' vital signs were monitored and recorded at each time point for both groups (Table 2). Data analysis showed no significant differences between the EOI and control groups at any recorded time point ($p > 0.05$).

3.3 Analgesic effect

Sufentanil consumption via the analgesic pump at 24 hours postoperatively was significantly lower in the EOI group compared to the control group (median: 52 μg (50–54) *vs.* 54 μg (52–54); difference in medians with 95% CI: 0.000 to 2.000, $p = 0.027$, calculated using the Mann-Whitney U test and Hodges-Lehmann estimate) (Table 3). The VAS pain scores demonstrated significantly higher incision pain in the control group compared to the EOI group at 1 hour postoperatively (median: 2 (1–4) *vs.* 1 (0–2); difference in medians with 95% CI: 0.000 to 2.000, $p = 0.005$, calculated using the Mann-Whitney U test and Hodges-Lehmann estimate). However, there were no significant differences between the two groups in VAS scores for visceral or shoulder pain. When comparing VAS scores for incisional and visceral pain at 1 hour, the control group exhibited significantly higher scores for incisional pain ($p < 0.05$) (Fig. 3). Regarding rescue analgesic consumption, tramadol use at 1 hour postoperatively was significantly higher in the control group than in the EOI group (median: 0 (0–50) *vs.* 0 (0–0); difference in medians with 95% CI: 0.000 to 0.000, $p = 0.038$, calculated using the Mann-Whitney U test and Hodges-Lehmann estimate). No significant differences in incision pain scores were observed among different surgical types (Table 4).

3.4 Patient assessment indicators and nerve block complications

No significant differences were observed between the two groups in postoperative recovery quality, as measured by the QoR-15 score, or in assessments of anxiety (SAS score) and cognitive function (MMSE score). Additionally, the incidence of nerve block-related complications did not differ signifi-

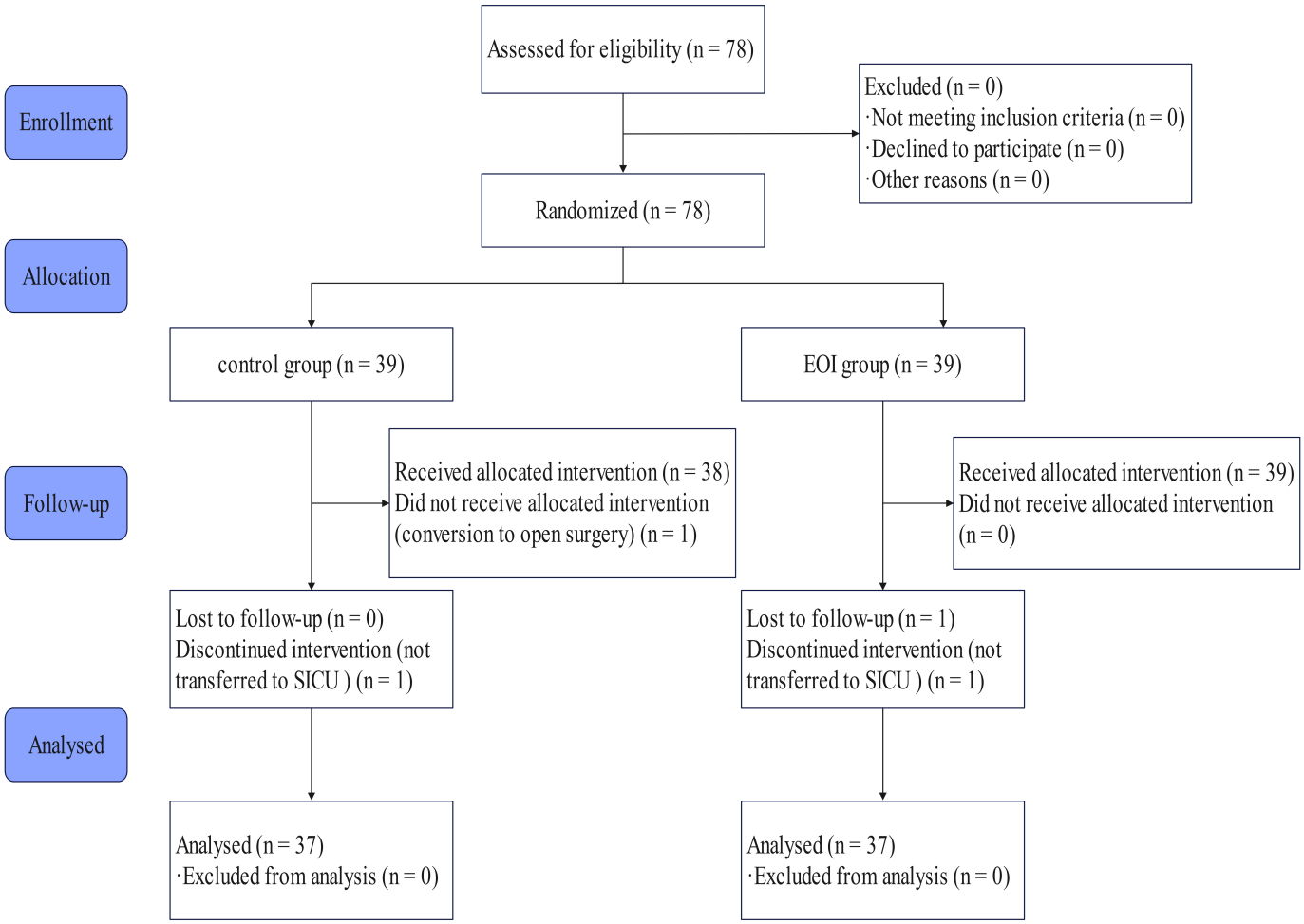

FIGURE 2. The CONSORT flow diagram of the study design. EOI: external oblique intercostal; SICU: surgical intensive care unit.

TABLE 1. Baseline patient characteristics and perioperative data.

Variables	Control group (n = 37)	EOI group (n = 37)	$t/Z/\chi^2$	*p*-value
Gender[c]				
Male	20 (54.1%)	23 (62.2%)	0.500	0.480
Female	17 (45.9%)	14 (37.8%)		
ASA physical status classification[c]				
II	25 (67.6%)	22 (59.5%)	0.525	0.469
III	12 (32.4%)	15 (40.5%)		
Age (yr)[b]	61 (54.5, 69)	59 (54.5, 69.5)	−0.222	0.824
BMI (kg/m^2)[a]	22.14 ± 3.22	23.54 ± 3.92	−1.679	0.098
Types of surgery[c]				
Partial gastrectomy	15 (40.5%)	11 (29.7%)	2.879	0.406
Peripheral pancreatectomy	4 (10.8%)	9 (24.3%)		
Whipple procedure	2 (5.4%)	3 (8.1%)		
Minor hepatectomies	16 (43.2%)	14 (37.8%)		
Surgical time (h)[b]	3.5 (2.9, 4.6)	3.6 (1.8, 4.95)	−0.173	0.863
Anesthesia time (h)[b]	3.8 (3.2, 4.85)	4.0 (2.15, 5.3)	−0.135	0.892
Number of surgical incisions[b]	5 (5, 5)	5 (5, 5)	−1.000	0.317
Number of drainage tubes	2 (2, 2)	2 (2, 2)	−0.585	0.558
HR (bpm)[a]	79.24 ± 9.92	78.97 ± 10.61	0.113	0.910
MAP (mmHg)[a]	125.65 ± 17.97	130.46 ± 20.77	−1.065	0.290
SpO_2 (%)[b]	98 (97.99)	98 (97.98.5)	−0.522	0.602
RR (breaths/min)[a]	16.92 ± 1.53	17.11 ± 2.23	−0.425	0.672

Note: [a]Values are presented as mean ± SD. [b]Values are presented as medians (IQR). [c]Values are presented as number (%). Abbreviations: ASA: American Society of Anesthesiologists; BMI: body mass index; HR: heart rate; MAP: mean arterial pressure; SpO_2: pulse oxygen saturation; RR: respiratory rate; EOI: external oblique intercostal.

TABLE 2. Vital signs of the two groups at each time point.

Variables	Time	Control group (n = 37)	EOI group (n = 37)	Estimated Difference, Control *vs.* EOI (95% CI)	*p*-value
HR (bpm)[a]					
	1 h	76.58 ± 11.32	77.46 ± 13.00	−0.892 (−6.540 to 4.756)	0.754
	4 h	75.70 ± 11.37	80.27 ± 10.13	−4.568 (−9.558 to 0.423)	0.072
	8 h	73.46 ± 13.52	71.68 ± 10.49	1.784 (−3.823 to 7.390)	0.528
	24 h	75.03 ± 10.44	76.32 ± 11.28	−1.297 (−6.333 to 3.738)	0.609
MAP (mmHg)[a]					
	1 h	122.73 ± 20.43	122.95 ± 14.10	−0.216 (−8.368 to 7.935)	0.958
	4 h	113.62 ± 14.98	117.78 ± 17.10	−4.162 (−11.613 to 3.289)	0.269
	8 h	100.76 ± 13.86	104.78 ± 14.19	−4.027 (−10.529 to 2.475)	0.221
	24 h	111.16 ± 13.91	113.84 ± 14.09	−2.676 (−9.164 to 3.812)	0.414
SpO_2 (%)[b]					
	1 h	97 (96.98)	97 (96.97)	0.000 (0.000 to 1.000)	0.430
	4 h	97 (97.99)	98 (96.99)	0.000 (−1.000 to 1.000)	0.842
	8 h	98 (97.98)	98 (97.99)	0.000 (−1.000 to 1.000)	0.889
	24 h	97 (96.99)	98 (97.98)	0.000 (−1.000 to 0.000)	0.598
RR (breaths/min)[a]					
	1 h	17.19 ± 1.96	17.00 ± 1.78	0.189 (−0.677 to 1.056)	0.665
	4 h	15.97 ± 1.94	15.89 ± 1.81	0.081 (−0.787 to 0.949)	0.853
	8 h	15.86 ± 1.81	16.19 ± 1.18	−0.324 (−1.134 to 0.486)	0.427
	24 h	15.65 ± 1.80	15.89 ± 1.51	−0.243 (−1.012 to 0.525)	0.530

Note: [a]Values are presented as mean ± SD. [b]Values are presented as medians (IQR). Abbreviations: CI: confidence interval; HR: heart rate; MAP: mean arterial pressure; SpO_2: pulse oxygen saturation; RR: respiratory rate; EOI: external oblique intercostal.

TABLE 3. Analgesic drug consumption and VAS scores.

Variables	Time	Control group (n = 37)	EOI group (n = 37)	Estimated Difference, Control *vs.* EOI (95% CI)	*p*-value
Analgesic Pump Sufentanil Consumption (μg)					
	1 h	2 (2, 2)	2 (2, 2)	0.000 (0.000 to 0.000)	0.398
	4 h	8 (8, 10)	8 (8, 10)	0.000 (0.000 to 0.000)	0.294
	8 h	18 (16, 20)	16 (16, 20)	0.000 (0.000 to 2.000)	0.055
	24 h	54 (52, 54)	52 (50, 54)	2.000 (0.000 to 2.000)	0.027
			VAS score		
Incisional pain					
	1 h	2 (1, 4)	1 (0, 2)	1.000 (0.000 to 2.000)	0.005
	4 h	1 (0, 2)	1 (0, 2)	0.000 (0.000 to 1.000)	0.317
	8 h	1 (0, 2)	1 (0, 2.5)	0.000 (−1.000 to 0.000)	0.188
	24 h	0 (0, 2)	0 (0, 1)	0.000 (0.000 to 0.000)	0.190
Visceral pain					
	1 h	0 (0, 1)	1 (0, 1)	0.000 (−1.000 to 0.000)	0.145
	4 h	1 (0, 2.5)	1 (0, 2)	0.000 (−1.000 to 0.000)	0.891
	8 h	0 (0, 1)	0 (0, 2)	0.000 (0.000 to 0.000)	0.850
	24 h	0 (0, 1)	0 (0, 1)	0.000 (0.000 to 0.000)	0.833
Shoulder pain					
	1 h	0 (0, 0)	0 (0, 0)	0.000 (0.000 to 0.000)	1.000
	4 h	0 (0, 0)	0 (0, 0)	0.000 (0.000 to 0.000)	0.317
	8 h	0 (0, 0)	0 (0, 0)	0.000 (0.000 to 0.000)	0.628
	24 h	0 (0, 1)	0 (0, 0)	0.000 (0.000 to 0.000)	0.291
Tramadol consumption (mg)					
	1 h	0 (0, 50)	0 (0, 0)	0.000 (0.000 to 0.000)	0.038
	4 h	0 (0, 50)	0 (0, 25)	0.000 (0.000 to 50.000)	0.055
	8 h	50 (0, 50)	0 (0, 50)	0.000 (0.000 to 50.000)	0.100
	24 h	50 (0, 100)	0 (0, 50)	0.000 (0.000 to 50.000)	0.106

Note: Data are presented as medians (IQR). Abbreviations: CI: confidence interval; VAS: visual analog scale; EOI: external oblique intercostal.

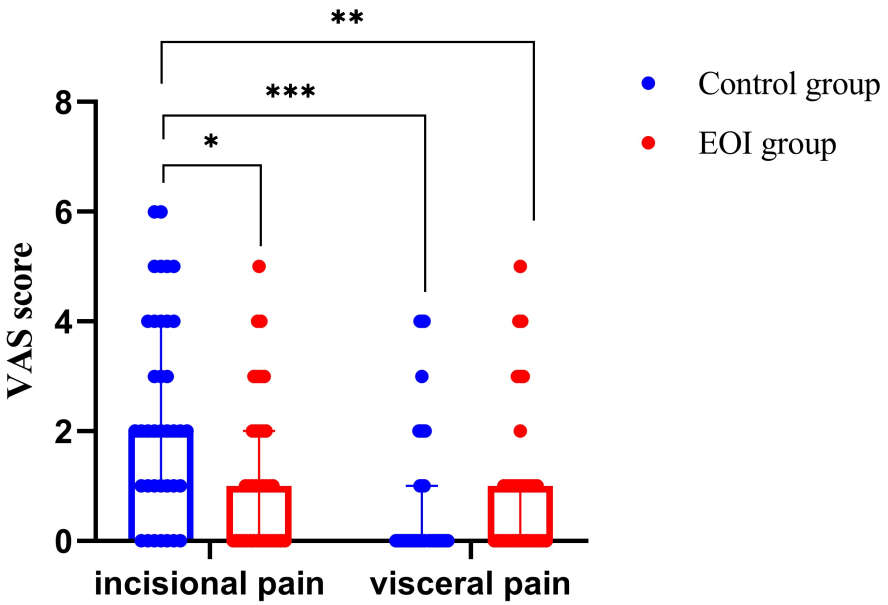

FIGURE 3. Comparison of incision pain and visceral pain between the two groups at different time points. Note: *$p <$ 0.05, **$p <$ 0.01 and ***$p <$ 0.001 indicate statistically significant differences between the two groups at the same time point. VAS: visual analog scale; EOI: external oblique intercostal.

TABLE 4. Incision pain score between different surgical types.

Group	Gastrectomy	Hepatectomy	Pancreatectomy	*p*-value
Control				
1 h	2 (1, 4)	2 (1, 3)	2 (0.75, 5.25)	0.761
4 h	1 (1, 2)	1 (0, 2)	1 (0, 3.25)	0.996
8 h	1 (0, 2)	1 (0, 2.75)	0 (0, 1.5)	0.528
24 h	0 (0, 2)	0 (0, 1.75)	0 (0, 1.25)	0.819
EOI				
1 h	1 (0, 2)	1 (0, 2.25)	0 (0, 1.75)	0.377
4 h	0 (0, 3)	0 (0, 2)	2 (0, 2)	0.452
8 h	2 (0, 3)	1 (0, 2.25)	1 (0, 2)	0.790
24 h	0 (0, 1)	0 (0, 1)	0 (0, 0)	0.625

Note: Data are presented as medians (IQR). EOI: external oblique intercostal.

TABLE 5. Patient assessment indicators and nerve block complications.

Variables	Control group (n = 37)	EOI group (n = 37)	*p*-value
QoR-15 score[a]	146 (140, 147)	147 (142, 148)	0.148
SAS score[a]	28 (26, 30)	28 (26, 29)	0.386
MMSE score[a]	29 (29, 30)	29 (29, 30)	0.720
Complications[b]			
Puncture hemorrhage (Y/N)	0/37	2/35	
Local hematoma (Y/N)	0/37	0/37	
Local infection (Y/N)	0/37	0/37	0.999
Nerve injury (Y/N)	0/37	0/37	
Allergic reaction (Y/N)	0/37	0/37	

Note: [a]Values are presented as medians (IQR). [b]Values are presented as number (%). Abbreviations: QoR-15: 15-item Quality of Recovery scale; SAS: Self-Rating Anxiety Scale; MMSE: Mini-Mental State Examination; EOI: external oblique intercostal; Y/N: yes/no.

cantly between the two groups ($p > 0.05$) (Table 5).

4. Discussion

The findings of this study demonstrated that sufentanil consumption via the analgesic pump within 24 hours post-extubation was significantly lower in the EOI group compared to the control group. Additionally, incision pain scores and rescue analgesic consumption within the first hour after extubation were significantly reduced in the EOI group. However, no significant differences were observed between the two groups in terms of vital signs, overall patient assessment indicators, or nerve block complication rates at any time point.

Postoperative pain following laparoscopic surgery primarily arises from three sources: incision site pain, visceral wound pain, and shoulder pain induced by pneumoperitoneum. Among these, incision pain constitutes the predominant component of postoperative pain [17]. Patients with preexisting conditions, perioperative respiratory complications, or those undergoing abdominal, trauma or emergency surgery have an increased likelihood of requiring postoperative intensive care [18]. Studies have indicated that for upper abdominal surgery, regional anesthesia techniques should target the intercostal nerves corresponding to the T6–T10 dermatomes to achieve effective analgesia in the upper abdominal wall [19]. Furthermore, EOI block has been reported to provide superior postoperative analgesia for the upper abdomen compared to TAP block [20].

The results of this study indicate that incision and visceral pain were the primary sources of postoperative pain following upper abdominal surgery, with EOI block demonstrating a significant effect in relieving incision pain. Although previous studies have reported no significant difference in IV-PCA drug consumption with EOI block [21], our findings revealed a difference in sufentanil consumption at 24 hours postoperatively, while the most pronounced reduction in incision pain was observed at 1 hour postoperatively. This discrepancy may be attributed to the programmed interval administration and lockout times of the postoperative analgesia pump, which could necessitate additional rescue analgesia when patients experience incision pain in the early postoperative period. Although statistical analysis demonstrated a significant reduction in sufentanil consumption in the EOI group, the clinical

significance of this difference should be interpreted with caution. Additionally, the lower tramadol consumption at 1 hour postoperatively in the EOI group aligns with findings from previous studies, which suggest that EOI block reduces opioid requirements after surgery [22].

In this study, nerve block was performed preoperatively as a preemptive analgesia strategy, aiming to prevent central sensitization, which can persist even after the analgesic effect of the drug has subsided, thereby reducing postoperative pain intensity and analgesic requirements [23]. The VAS score for incisional pain was significantly lower in the EOI group than in the control group, whereas no significant difference was observed in visceral pain scores. This finding may be explained by the fact that fascial plane blocks primarily provide somatic analgesia and are less effective for visceral pain relief [24]. Postoperative shoulder pain following laparoscopy is closely associated with factors such as pneumoperitoneum pressure and intraoperative respiratory settings, with reported incidence rates of as high as 76.7% [25, 26]. In this study, the incidence of shoulder pain was lower than previously reported, which may be attributed to effective carbon dioxide removal at the end of surgery and the relatively small sample size.

While nerve blocks may be associated with complications such as vascular injury, hematoma and nerve damage [27], EOI block was performed as a fascial plane block technique in this study. Continuous monitoring of vital signs and nerve block complications over 24 hours revealed no significant differences between the two groups, supporting the feasibility and safety of ultrasound-guided EOI block. We believe that the use of ultrasound visualization played a key role in ensuring precise needle placement and reducing complications [28].

To account for potential differences in pain perception among patients undergoing different surgical procedures, subgroup analyses were performed based on surgical type [24]. Additionally, the study considered the experience of surgeons and anesthesiologists, ensuring that all procedures were conducted by experienced professionals to minimize the impact of variability in surgical or anesthesia techniques on the study results.

Elderly patients with higher ASA classification scores and those admitted to the SICU are at a greater risk of anxiety and delirium during hospitalization, which can affect postoperative quality of life [29–31]. Despite the lower VAS scores observed in the EOI group, there were no significant differences between the two groups in the QoR-15, SAS or MMSE scores, which may be explained by the timely administration of analgesic medication when the VAS score reached or exceeded 4 points, which helped maintain overall patient comfort.

This study has several limitations. First, as a single-center study, its generalizability may be limited due to the specific institutional practices. Second, given the duration of the nerve block effect, this study did not assess outcomes beyond 24 hours postoperatively, limiting the understanding of long-term analgesic efficacy and potential complications. Lastly, the primary outcome measure was analgesic consumption, which may not fully capture patients' pain experiences, as some individuals may have opted for additional rescue medications rather than relying solely on the analgesic pump.

5. Conclusions

EOI block with ropivacaine effectively reduces postoperative incision pain and decreases the need for rescue analgesics in patients undergoing major abdominal laparoscopic surgery. Additionally, this technique demonstrates a favorable safety profile, supporting its use as an effective regional analgesic approach in this patient population.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

HCH and JL—designed the study and carried them out; wrote the manuscript. XY—supervised the data collection; analyzed the data. LZ—performed the research; supervised the data collection. YPL—provided help and suggestions; reviewed the draft of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the Institutional Review Board (IRB) of the First Hospital of Jiaxing (IRB approved registration number: 2024-LY-673). Enrolled participants provided written informed consent.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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