ORIGINAL RESEARCH

Effect of Ultrasound-Guided Erector Spinae Plane Block on Pain After Laparoscopic Transabdominal Preperitoneal Repair: A Prospective, Double-Blind, Randomized Controlled Study

Lei Duan, MM; Zepeng Wang, MM; Mengliang Sun, MM; Ligang Huang, MM; Qing Ye, MM; Haiquan Wang, MM

ABSTRACT

Objective • The present study was performed to evaluate the effect of ultrasound-guided erector spinae plane block (ESPB) on pain after laparoscopic transabdominal preperitoneal (TAPP) repair. Therefore, improved postoperative pain management is crucial for enhancing the overall patient experience and recovery.

Methods • This prospective, double-blind, randomized controlled trial enrolled 40 male patients with a unilateral inguinal hernia at Xi'an Aerospace General Hospital from November 1, 2020, to February 1, 2021. Participants were assigned through a random number table at a 1:1 ratio to receive either ESPB with 20 ml 0.5% ropivacaine in the experimental group (Group E) or ESPB with 20 ml normal saline in the control group (Group C), with 20 cases in each group. The primary outcome was assessed using visual analogue scale (VAS) scores for exercise pain at 2h, 6h, 12h, 18h, and 24h postoperatively. Secondary outcomes included time lapses before patient-controlled intravenous analgesia (PCIA) use, intraoperative remifentanil usage, additional sufentanil, postoperative nalbuphine consumption, analgesic remedies at 24h postoperatively, and incidence of postoperative adverse events.

Results • Group E provided more pain mitigation for patients than Group C, as evidenced by the significantly lower VAS scores during exercise pain at 2h (Group C: 1.95±1.19; Group E:4.00±1.38), 6h (Group C: 2.00±1.12; Group E:3.90±1.37), and 12h (Group C: 2.05±1.05; Group E:3.55±1.36) postoperatively ($P < .05$), and the pain mitigation for Group C-was significant only at 18h and 24h postoperatively compared to at 2h postoperatively ($P < .05$). Group E resulted in significantly reduced intraoperative use of remifentanil and, additional sufentanil and postoperative nalbuphine consumption versus Group C ($P < .05$). Group E exhibited a better pain tolerance than Group C, as demonstrated by the longer time lapse before the use of PCIA (RR value=5.709, t=8.446, $P < .05$). Group C required more analgesic remedies within 24 h after surgery than Group E ($P < .05$). Group E did not increase the risk of postoperative adverse events, given the absence of statistical significance in the intergroup comparison ($P > .05$).

Conclusion • Ultrasound-guided ESPB demonstrates notable benefits by decreasing intraoperative and postoperative anesthetic drug requirements, enhancing pain management, and elevating postoperative comfort and quality of life for patients. While acknowledging the study's limitations, it is crucial to highlight the potential clinical implications of these findings. The incorporation of ESPB with ropivacaine into postoperative pain management protocols could represent a significant advancement in clinical practice. The observed improvements in pain management and reduced reliance on anesthetic drugs may lead to more tailored and efficient postoperative care, potentially enhancing patient recovery experiences. Further research and practical implementation studies are warranted to fully elucidate the specific impact and optimal integration of ESPB with ropivacaine within broader clinical settings. (*Altern Ther Health Med.* [E-pub ahead of print.])

Lei Duan, MM; Zepeng Wang, MM; Ligang Huang, MM; Qing Ye, MM; Department of Anesthesiology, Xi'an Aerospace General Hospital, Xi'an, China. **Mengliang Sun, MM;** Intensive Care Medicine Center of Xi'an People's Hospital, Xi'an, China. **Haiquan Wang, MM; D**epartment of General Surgery, Xi'an Aerospace General Hospital, Xi'an, China.

Corresponding author: Haiquan Wang, MM
E-mail: quanshanlin71549@163.com

INTRODUCTION

Laparoscopic transabdominal preperitoneal (TAPP) repair, a common surgical procedure in abdominal wall surgery, features a lower risk of recurrence and postoperative complications and provides a shorter length of stay compared with open procedures.[1] However, despite these advantages, TAPP repair faces a significant and pressing challenge - the management of severe postoperative pain, with most patients still requiring high-dose opioids for pain relief 24 to 48 hours

after surgery.[2,3] Inguinal hernia repair is one of the most common and successful operations performed worldwide. It is estimated that the lifetime risk of inguinal hernia is 27%-43% for men and 3%-6% for women.[4,5] Chronic pain is a common long-term complication after hernia repair. About 0.5-6% of patients suffer from chronic pain after laparoscopic TAPP repair, which seriously affects patients' quality of life.[6-8]

These approaches are associated with advantages such as reduced postoperative pain, accelerated recovery, decreased complications, and improved aesthetics. However, it is important to note that while these techniques offer promising benefits, challenges in pain management may still exist. For instance, minimally invasive approaches like laparoscopy, despite their advantages, have limitations such as restricted visual field and space, necessitating a high level of surgical expertise.[11] Some minimally invasive methods, like natural orifice endoscopic surgery, can result in incomplete closure of puncture sites, visceral leakage, abdominal contamination, and an increased risk of infection.

These challenges underscore the ongoing need for more effective pain management strategies in minimally invasive procedures. While laparoscopic techniques have been widely used in TAPP repair,[12,13] understanding the pain management implications of both established and innovative surgical methods is crucial for advancing patient care and optimizing outcomes in these procedures. Further exploration is needed to determine whether these techniques offer comprehensive solutions to postoperative pain or if additional strategies are necessary to address this critical aspect of patient recovery.

The use of regional blocks is known for its favorable analgesic effects in abdominal surgery. In this context, ultrasound-guided erector spinae plane block (ESPB), a novel fascial compartment block technique, was introduced in 2016 for managing severe neuropathic pain and acute postoperative pain in the thoracic back.[14] ESPB, based on its anatomical foundation, involves blocking the ventral branch of the spinal nerve and the traffic branch of sympathetic nerve fibers. This technique provides both somatosensory blockade and visceral sensory blockade, theoretically meeting analgesic requirements for thoracolumbar surgery. ESPB is characterized by its simple and safe operation with few complications.[14] Meanwhile, ultrasound-guided visualization reduces the incidence of complications such as nerve damage and results in more accurate localization of anesthesia.[15] Nonetheless, little knowledge is available related to the effects of ESPB on pain after laparoscopic hernia.

It has been shown that after injection of local anesthetic into the fascial space at the T5 transverse process, the drug could diffuse down the fascial space to the area innervating the abdominal spinal nerve roots[16] and that a single loading dose of 30 ml of ESPB could diffuse to 9 segments and 3.4 ml could cover 1 segment.[17] In the context of laparoscopic TAPP repair, ESPB holds particular relevance due to its capacity to effectively block the innervation of the Trocar puncture site. This area is served by the inferior iliac abdominal-iliac inguinal nerve, which comprises the ventral branch of the T10 spinal nerve and the anterior branches of the T12 to L1 spinal nerves. Notably, a cadaveric study utilizing computed tomography demonstrated that the drug diffusion from ESPB at the T7 transverse process extends to encompass the relevant surgical region from the cephalic end to the level of the T4 thoracic vertebra and from the caudal end to the level of the L3 transverse process.[18] The theoretical completeness of dermal nerve block achievable with a single injection of ESPB aligns with the surgical requirements of laparoscopic TAPP repair. Moreover, previous reports indicate that the prolonged duration of action of regional nerve blocks, exceeding 20 hours, when utilizing 0.5% ropivacaine for trunk nerve blocks, results in significant pain relief 24 hours postoperatively.[19] These unique characteristics make ESPB a promising and advantageous approach for pain management in the specific context of laparoscopic TAPP repair.

In summary, this study aims to determine the effectiveness of unilateral ESPB with 0.5% 20 ml ropivacaine at the T7 transverse process in alleviating pain 24 hours postoperatively for patients undergoing laparoscopic TAPP repair, with a specific focus on the painful area from T10 to L1. The research objectives include assessing the analgesic efficacy of ESPB in this context and understanding its impact on postoperative pain management. To achieve these aims, the study design incorporates a detailed methodology that outlines the process of patient recruitment, intervention administration, and outcome assessments. This methodology section will provide a comprehensive overview of the research approach and data collection procedures.

MATERIALS AND METHODS

Participants

This study received approval from the Ethics Committee of Xi'an Aerospace General Hospital (approval number: XHTZYY-2020-LL-09). The research adhered to the Consolidated Standards of Reporting Trials (CONSORT) statement and the Declaration of Helsinki. Informed consent was obtained from all participants after providing detailed information about the study procedures, potential risks involved, and the purpose of the research. The informed consent form explicitly outlined the nature of the intervention, the voluntary nature of participation, and the confidentiality of participant information. Participants were given the opportunity to ask questions and seek clarification before voluntarily agreeing to participate in the study. The study included 40 male patients with a unilateral inguinal hernia from November 1, 2020, to February 1, 2021, at Xi'an Aerospace General Hospital, aged 18 to 70 years, with a body mass index (BMI)-20 to 35 kg/m^2.

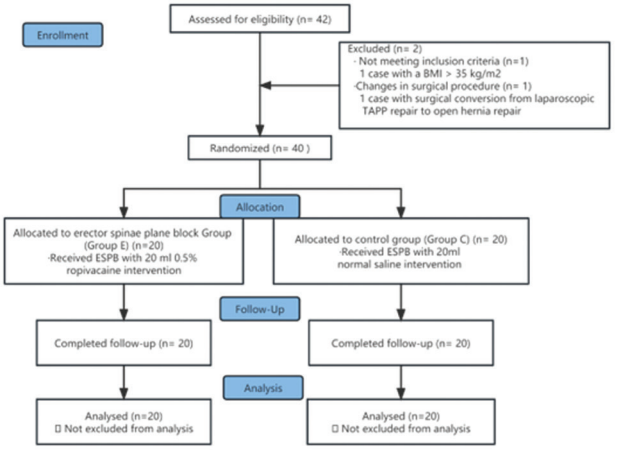
Participants with American Society of Anesthesiologists (ASA) classification grade I to II were randomly assigned to the experimental group (Group E) or the control group (Group C) in a 1:1 ratio. The randomization process involved the use of a random number table generated by an independent statistician who was not involved in the study. The random numbers were then assigned to participants in

consecutive order as they were enrolled in the study. This rigorous process was implemented to ensure transparency and eliminate bias in the assignment of participants to their respective groups. The allocation sequence and group assignments were concealed until after participants were enrolled and their baseline characteristics were recorded.

Inclusion criteria: (1) patients met the diagnostic criteria of unilateral inguinal hernia; (2) tolerance to laparoscopic surgery and anesthesia; (3) clinical and follow-up data were complete and reliable.

Exclusion criteria: (1) patients with a history of abdominal surgery: May affect the procedure due to altered anatomy or adhesions; (2) Severe systemic diseases or anesthesia issues: Excluded to ensure safety and avoid unrelated complications; (3) coagulation disorders: May increased bleeding risk during surgery; (4) Puncture contraindications or infections: To maintain aseptic conditions and minimize complications; (5) allergy to local anesthetics: May risk of severe allergic reactions; (6) refusal of nerve block: May impact intervention uniformity; (7) Cognitive or communication problems: Difficulty with consent, instructions, and event reporting; (8) Participating in other trials: Prevents conflicting treatments and participant burden,as shown in Figure 1.

Figure1. CONSORT study flow diagram.



Trial design

This study was a prospective, double-blind, randomized controlled trial. The patient grouping data and the ultrasound-guided puncture injection drug preparation method were kept in consecutively numbered opaque envelopes sealed by this statistical expert before surgery. On the day of surgery, an anesthesiologist not involved in this study opened the envelope ,prepared the appropriate medication according to the drug instructions and performed intraoperative general anesthesia for the participants. Postoperative follow-up was done by nurses who were spared from this study. The statistical experts had an emergency unblinding envelope containing information of all grouping information in this study, which was used for emergency unblinding in the event of serious adverse events.

Treatment methods

Interventions. Both groups of patients fasted for 8 h and refrained from clear liquids for 2 h before surgery. After entering the operating room, the electrocardiogram (ECG), noninvasive blood pressure (NBP), pulse oximetry (SpO_2), and heart rate (HR) were monitored. The patients received 40mg of parecoxib sodium (H20193248,20mg, Yangtze River Pharmaceuticals) through intravenous injection and 1.0ug/kg/hr of dexmedetomidine (H20183220, 2ml:0.2mg, Yangtze River Pharmaceuticals) by continuous intravenous pumping.

With the patient in the lateral position, the spine of the 7th thoracic vertebra was marked by palpation, the skin was sterilized, and a high-frequency line array ultrasound probe (frequency 6-13 MHz) of a portable ultrasound instrument (S-series, Sono Sound, USA) was placed longitudinally about 3.0 cm next to the spine of the 7th thoracic vertebra to perform imaging. Ultrasound images from top to bottom showed the rhomboid, erector spinae and the tip of the transverse process of the 7th thoracic vertebra (the rhomboid would be missing on ultrasound images at the T7 vertebra because the inferior border of the rhomboid ends at the scapular spine margin at the T6 vertebral body) (Figure 2). After local anesthesia infiltration (3 ml 2.0% lidocaine), a 22 G × 70 mm neuroclosure needle (PM-Echo, Hachimitsu Co., Ltd., Japan) was injected from the cephalad to the caudal plane. After the tip of the puncture needle reached the tip of the transverse process of the 7th thoracic vertebra (Figure 3), 200mg of 0.5% ropivacaine (H20103636, Yichang Renfu Pharmaceutical) was administered. The diffusion of local anesthetic solution in the deep surface of the erector spinal muscle was visible under ultrasound (Figure 4). Group C received the same intervention method and injection of an equal volume of saline.

The choice of parecoxib sodium and dexmedetomidine was made considering their specific analgesic and sedative properties, respectively. Parecoxib, as a selective COX-2 inhibitor, is known for its efficacy in providing postoperative pain relief. Dexmedetomidine, an alpha-2 adrenergic agonist, offers sedation and analgesia while minimizing the risk of respiratory depression. It's essential to note potential adverse effects associated with these medications: (1) Parecoxib Sodium: 1) Gastrointestinal Effects: dyspepsia, nausea, vomiting, and diarrhea; 2) Cardiovascular Effects: edema, hypertension, flushing. (2) Dexmedetomidine: 1) Cardiovascular Effects: bradycardia, hypotension, arrhythmias; 2) Central Nervous System Effects: sedation, dizziness, headache and insomnia or vivid dreams during sedation; 2) Respiratory Effects: respiratory depression (especially if used with other sedatives or opioids); 3) Gastrointestinal Effects: nausea and vomiting.

The selected doses for each medication were determined based on established clinical efficacy and safety profiles. It's crucial for healthcare providers to monitor patients closely for any potential adverse reactions and to adjust doses as

Figure 2. Ultrasound image of the T7 transverse process in the paramedian sagittal plane.Abbreviations: TM, Trapezius muscle; ES, erector spinal muscle; TP, transverse process of the T7.

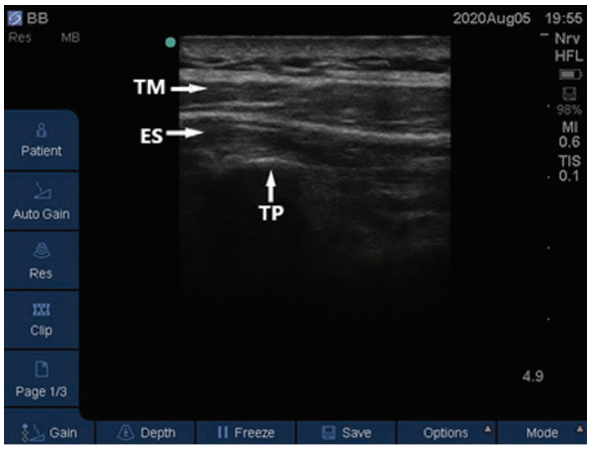


Figure 3. Ultrasound image of the tip of the puncture needle reaching the tip of the T7 transverse process.Abbreviations: TM, Trapezius muscle; ES, erector spinal muscle; TP, transverse process of the T7. Red arrow: Puncture needle position.

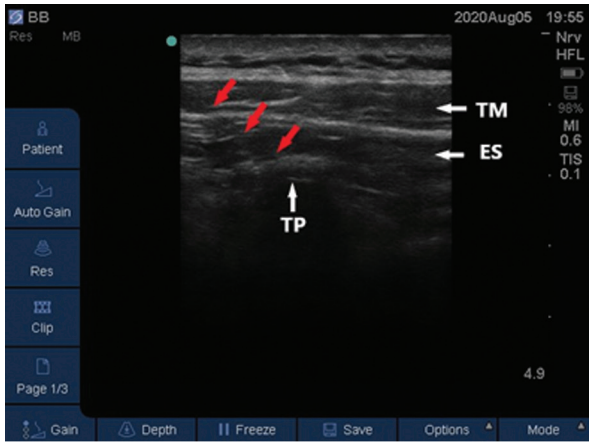
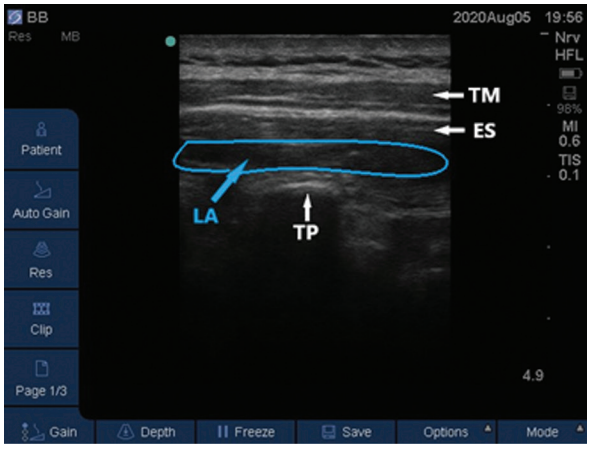


Figure 4. Ultrasound image of the T7 transverse process after injection of the drug.



Abbreviations: TM,Trapezius muscle; ES, erector spinal muscle; TP, transverse process of the T7; LA, local anesthetic. Red arrow: Puncture needle position.

needed. Patients should be informed about the possible side effects, and healthcare professionals should be prepared to address any complications promptly.

Anesthesia. Both groups of patients were treated with surgical intervention received general anesthesia with tracheal intubation. The rapid induction method of general anesthesia was performed, with an intravenous injection of 0.3 μg/kg of sufentanil (H20054171, 1 ml: 50 μg, Yichang Renfu Pharmaceutical) + 2 mg/kg of intravenous injection of propofol (H20123138,20 ml: 0.2 g, Envac Pharmaceutical) + 0.1 mg/kg of intravenous injection of cisatracurium benzoate (H20060869, 10 mg, Hengrui Pharmaceutical). After the anesthesia index decreased to 40-60 (ConView YY-105, Zhejiang Puke Medical) and the patient's laryngeal muscles relaxed, tracheal intubation was performed. Mechanical ventilation in volume-controlled mode was conducted, and the respiratory parameters were set at 8 ml/kg tidal volume, 12 breaths/min, and 40% inhaled oxygen concentration. Anesthesia was maintained with isoflurane (H20020267,100ml/bottle, Lunanbetter Pharmaceutical) 1.2%-2.0% inhalation + remifentanil (H20030199,1mg/stem, Yichang Renfu Pharmaceutical) (0.1-0.5) μg/kg/min through intravenous pumping. Intraoperatively, the patient's PetCO2 was maintained at 35 mmHg~45 mmHg, Ai at 40~60, and pneumoperitoneum pressure at 12 mmHg~14 mmHg. Additional sufentanil (5-10 μg) was administered when hemodynamic parameters increased (HR or mean arterial pressure) above 15% of the pre-induction baseline value. Twenty minutes before the end of the surgery, 5 mg of tropisetron (H20061193, Jiangsu Hengrui Medicine) was administered intravenously to prevent postoperative nausea and vomiting, and isoflurane and remifentanil were discontinued after local anesthetic infiltration (10 ml 0.5% ropivacaine) in each of the three laparoscopic incisions at the end of surgery. Neostigmine (40μg/kg) and atropine (10μg/kg) were given to antagonize cisatracurium benzoate if necessary. After the patient's spontaneous breathing resumed and the indication for extubation was met, extubation was performed, and the patient was sent to the post-anesthesia care unit (PACU). The same Group of surgeons performed the surgery.

Postoperative analgesic methods. Postoperative multimodal analgesia was performed. Patients were admitted to the PACU with patient-controlled intravenous analgesia (PCIA) and oral administration of 200 mg/d of celecoxib.

The analgesic drugs used for PCIA included 2.0mg/kg of nalbuphine (H20130127, 2ml: 20mg, Yichang Renfu Pharmaceutical), 10mg of tropisetron, and normal saline, which were evenly mixed to prepare 100 mL of PCIA drug solution. The PCIA was used when the patient's postoperative visual analogue scale (VAS) scores ≥3 or requested analgesia. The first load of the analgesic pump was 5ml/h, bolus dose was 2ml/time, and the lockout time was 15min. The analgesic remedy was required when VAS scores ≥ 3 and the patient's self-perceived pain did not mitigate after 2 presses of PCIA within 30 min. Analgesic remedy referred to the intravenous

injection of 50mg of tramadol (22040811,0.1g/bottle, Ruiyang Pharmaceutical Co., Ltd.).

Outcome measures

Primary outcome measure: The intensity of exercise-induced pain was assessed using the Visual Analog Scale (VAS), is one of the pain rating scales and is often used to measure the intensity or frequency of various symptoms (20), which also a commonly used pain rating scale. VAS scores were recorded at 2h, 6h, 12h, 18h, and 24h postoperatively in both groups. The categorization of VAS scores was as follows: 0 (no pain), 1-3 (mild pain), 4-7 (moderate pain), and 8-10 (severe pain). Exercise pain was defined as pain in the abdomen experienced when the patient coughed (cough-induced pain). This categorization provides a clear framework for analyzing and interpreting the intensity of postoperative exercise-related pain in both study groups.

Secondary outcome measures: (1) The time-lapse of the first postoperative use of PCIA (the time interval between the end of the surgery and the first use of the PCIA when the patient had a VAS score≥ 3 or requested analgesia) was documented. (2) The intraoperative use of remifentanil and additional sufentanil consumption were recorded throughout the surgery; postoperative nalbuphine consumption was recorded at 6h, 12h, 18h, and 24h postoperatively. (3) The number of postoperative analgesic remedies for 24 h was recorded. (4) Incidence of postoperative nausea, vomiting, puncture site hematoma, and hypotension: Monitored and recorded during the first 24 hours postoperatively, with specific time points for any occurrences.

Statistical analysis

SPSS 18.0 software was employed for statistical analysis. Continuous variables were assessed for normality using the Kolmogorov-Smirnov test. Normally distributed measures were presented as mean ± standard deviation ($\bar{x}$ ± SD), and intergroup comparisons were conducted using the independent samples t-test. For intra-group comparisons, one-way ANOVA was applied, while repeated measures ANOVA was employed for multiple time points comparisons. Non-normally distributed measures were presented as median (interquartile range) [M(Q1, Q3)], and intergroup comparisons were performed using the Mann-Whitney U test.

Count data were expressed as cases [n(%)] and analyzed using the chi-square test or Fisher's exact probability analysis for intergroup comparisons, with a significance level set at α=0.05. A difference of $P < .05$ was considered statistically significant.

The estimation of sample size was performed using PASS 15 software. In the pilot study with 8 patients in each group, the 2-hour postoperative motor pain VAS scores (2.8±0.9 vs. 4.0±1.0) were compared with α=0.05, 1-β=0.90, and N2/N1=1. The calculation yielded 17 cases in each of the two groups. Anticipating a potential 10% loss to follow-up, we aimed for a final sample size of 20 cases in each group, totaling 40 cases. During the course of the study, 2 participants were lost to follow-up. To address this, 1 case with a BMI > 35 kg/m^2 and 1 case with surgical conversion from laparoscopic TAPP repair to open hernia repair were excluded. This information ensures transparency regarding participant retention and data handling strategies, maintaining the integrity of the study's findings.

Table 1. Patient characteristics

		Group E (n = 20)	Group C (n=20)	t/χ^2	*P* value
Age (year)		49.2±12.8	53.4±9.5	-1.148	.258
BMI(kg/m^2)		25.3±4.0	24.6±2.3	2.686	.497
ASA(n)	I	10	9	0.100	.752
	II	10	11		
Operative time (min)		76.9±10.7	81.5±12.1	-1.269	.212

Abbreviations: BMI, body mass index; ASA, American Society of Anesthesiologists.

Table 2. Postoperative VAS scores (points)

	Group E (n = 20)	Group C (n = 20)	*F*	*P* value
2 h postoperatively	1.95±1.19[a]	4.00±1.38		
6 h postoperatively	2.00±1.12[a]	3.90±1.37		
12 h postoperatively	2.05±1.05[a]	3.55±1.36		
18 h postoperatively	1.95 ± 1.00	2.50±1.19[b]		
24 h postoperatively	1.50 ± 0.83	1.85 ± 0.67[b]		
$F_{intergroup}$			62.656	<.001
F_{time}			11.994	<.001
$F_{intergroup \cdot time}$			3.929	.006

[a]indicates $P < .05$, compared with Group C.
[b]indicates $P < .05$,compared with 2h postoperatively in the same Group.

RESULTS

Patient characteristics

In this study, 42 patients were initially recruited, 1 case with a BMI > 35 kg/m^2 and 1 case with surgical conversion from laparoscopic TAPP repair to open hernia repair were excluded, and 40 patients were finally included, with 20 patients in each Group. No differences were found between the groups in terms of age ($P = .258$), BMI ($P = .497$), ASA ($P = .752$) and operative time ($P = .212$). (Table 1)

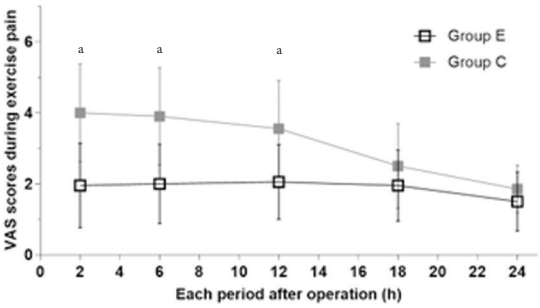
Postoperative VAS scores during exercise pain

Statistically significant differences were reported in the comparison of exercise pain VAS scores at the five timepoints during the 24h postoperative period between the two groups for intergroup, time and intergroup-time effect values ($P < .05$). Group E provided more pain mitigation for patients than Group C, as evinced by the significantly lower VAS scores at 2h, 6h, and 12h postoperatively ($P < .05$), and the pain mitigation for Group C was significant only at 18h and 24h postoperatively compared to at 2h postoperatively ($P < .05$). No statistical difference was observed in the comparison of exercise pain VAS scores during the Group 24 h after surgery in Group E (all $P > .05$) (Table 2, Figure 5).

Opioid consumption

Group E resulted in significantly reduced intraoperative use of remifentanil, intraoperative additional sufentanil and postoperative nalbuphine consumption versus Group C ($P < .0001$). (Table 3, Figure 6)

Figure 5. 24h postoperative VAS scores during exercise pain.

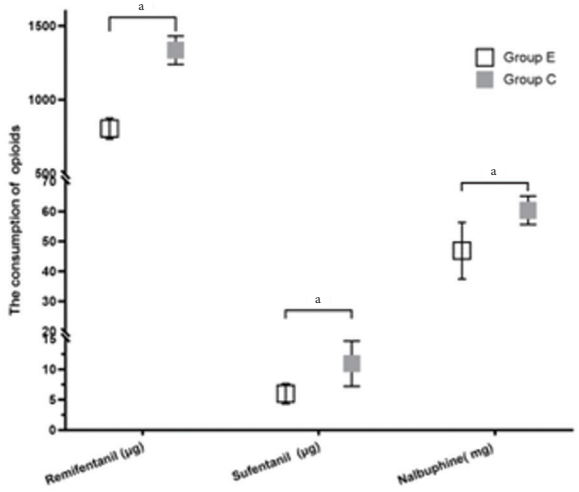


[a]indicates $P < .01$, compared with Group C.

Table 3. Opioid consumption

	Group E (n = 20)	Group C (n = 20)	*t*	*P* value
Intraoperative remifentanil consumption (μg)	804.16±70.47	1335.67±96.23	-19.928	<.000
Intraoperative additional sufentanil consumption (μg)	6.01±2.66	10.96±3.73	-4.833	<.000
Postoperative nalbuphine consumption (mg)	46.89±9.42	60.37±4.77	-5.712	<.000

Figure 6. Perioperative opioid consumption. Remifentanil: intraoperative remifentanil consumption; Sufentanil: intraoperative additional sufentanil consumption; Nalbuphine: postoperative nalbuphine consumption.



[a]indicates $P < .01$, compared with Group C.

Postoperative analgesia

Group E exhibited a better pain tolerance than Group C, as demonstrated by the longer time lapse before the use of PCIA (418.2±183.3 min vs. 68.1±27.7 min) (RR value=5.709, t=8.446, $P < .01$). Group C required more analgesic remedies within 24 h after surgery than Group E ($P < .05$). (Figure 7)

Postoperative adverse events

In Group E, 2 patients (10.0%) had nausea, 1 patient (5.0%) had vomiting, and 1 patient (5.0%) had hypotension. In Group C, 4 patients (20.0%) had nausea and 3 patients (15.0%) had vomiting. Group E did not increase the risk of postoperative adverse events given the absence of statistical significance in the intergroup comparison ($P > .05$), such as nausea, vomiting and hypotension. (Table 4)

Figure 7. Kaplan-Meier curve for the first time use of PCIA.

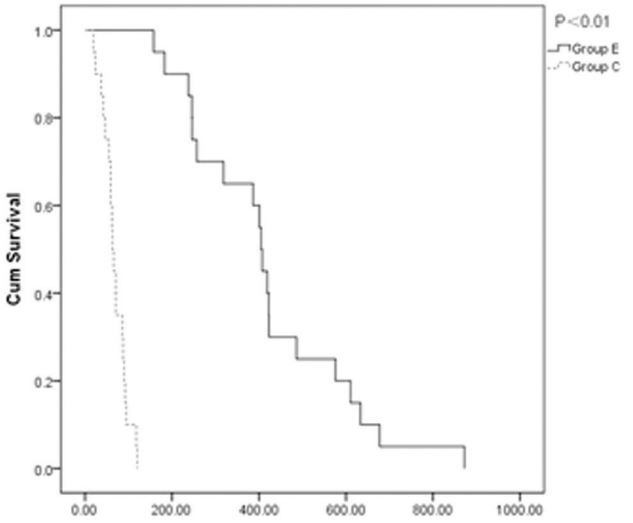


Table 4. Postoperative adverse events [n(%)]

	Group E (n = 20)	Group C (n = 20)	*P* value
Nausea	2(10.0)[a]	4(20)	.661
Vomiting	1(5.0)[a]	3(15)	.605
Puncture site hematoma	0	0	/
Hypotension	1(5.0)[a]	0	1.000

[a]indicates Fischer's exact test was used,compared with Group C.

DISCUSSION

ESPB is a novel regional block technique that was first proposed and successfully applied in 2016 by Forero et al.[14] This technique has shown promising results in the treatment of severe neuropathic pain and acute postoperative pain in the thoracic back. ESPB involves the administration of local anesthetic agents into the erector spinae plane, targeting specific nerve branches to provide effective analgesia. Understanding the basics of ESPB is crucial to appreciate its potential benefits, and in this study, we aim to evaluate its impact on postoperative pain management in patients undergoing laparoscopic TAPP repair.

After ultrasound-guided ESPB injection of local anesthetic into the deep surface of the erector spinal muscle, the local anesthetic will diffuse along this fascial space into the paravertebral space, blocking the dorsal, ventral, and communicating branches of the spinal nerve, thus providing extensive somatic and visceral pain suppression.[15,16] In laparoscopic TAPP repair, the Trocar puncture site is located in the inferior iliac abdominal-iliac inguinal innervation region consisting of the ventral branch of the T10 spinal nerve and the anterior branches of the T12 to L1 spinal nerves. Cadaveric studies have shown that after a single erector spinae plane injection using 20 ml of 0.01% methylene blue pigment in fresh cadavers, the diffusion ranged from approximately 3-7 spinal cord segments (mean 4.6), covering approximately 3.4 ml of a segment.[17-21]

Delving into the clinical significance of our findings, the reduction in opioid use and postoperative pain in patients undergoing laparoscopic TAPP repair holds several practical

implications. Firstly, it has the potential to significantly enhance patient recovery by minimizing the adverse effects associated with opioid medications. Reduced pain can contribute to earlier ambulation, respiratory function, and overall functional recovery. Moreover, a decrease in opioid requirements may positively impact hospital stay, as patients may experience improved comfort and earlier mobilization, potentially facilitating an expedited discharge process.

Beyond immediate postoperative outcomes, the implementation of ultrasound-guided ESPB in laparoscopic TAPP repair could have broader implications for overall healthcare outcomes. Reduced reliance on opioids aligns with current efforts to mitigate the opioid epidemic and may contribute to lower healthcare costs associated with managing opioid-related complications. By promoting a multimodal analgesic approach with ESPB, healthcare providers can potentially improve patient satisfaction and long-term well-being.

In practical terms, consider a scenario where a patient who has undergone laparoscopic TAPP repair experiences reduced pain, minimal opioid-related side effects, and a quicker return to normal activities. Such a case exemplifies the tangible benefits of ultrasound-guided ESPB, emphasizing its potential to positively influence patient outcomes and the broader healthcare landscape.

The present study found that ultrasound-guided ESPB could significantly reduce the intraoperative and postoperative anesthetic drugs consumption, reduce the severity of postoperative pain, and prolong the interval of postoperative use of anesthetic drugs to relieve pain (68.1±27.7 min vs. 418.2±183.3 min, RR=5.709, $P < .05$). The reason is that ESPB can selectively block the transmission of pain signals while sparing motor function. This is because the local anesthetic is deposited in a compartment that affects the sensory nerves, such as the intercostal nerves, but not the motor nerves. By sparing motor function, ESPB can mitigate motor pain that may occur during or after surgery, providing more precise and targeted analgesia. The duration of analgesia after TAPP repair with ESPB was indirectly reflected by the Kaplan-Meier survival curve of PCIA. Given that the ESPB in our study was performed preoperatively, the total duration of action using 20 ml of 0.5% ropivacaine was found to be slightly shorter than the results reported by Boules et al.,[22] taking into account the duration of surgery (1.3 ± 0.2) hours. This discrepancy is likely attributed to the difference in the type and concentration of local anesthetic drugs. Our study employed a 0.5% concentration of ropivacaine, and while effective, the optimal concentration for ESPB remains an area of exploration.

It's noteworthy to consider the potential implications of varying drug concentrations on the effectiveness and safety of the block. The choice of concentration may impact the duration of action, depth of analgesia, and potential side effects. As the field of regional anesthesia continues to evolve, future research could delve into optimizing drug concentrations to maximize the benefits of ESPB while ensuring patient safety. Exploring the dose-response relationship and comparing different concentrations could provide valuable insights for refining the technique and enhancing its clinical applicability.

A case report noted that in four patients who underwent laparoscopic TAPP repair with 0.5% 30 ml ropivacaine administered at the level of the T7 transverse process for bilateral ESPB, the median morphine consumption at 24 hours postoperatively was 18.7 [95% CI (0.0-43.0) mg and the NRS score at 24 hours postoperatively was 2.5 [95% CI (0.0-3.0)] to 3.5 [95% CI (3.0-5.0)].[23] This case report suggested that preoperative ESPB might reduce severe pain to mild or moderate after TAPP repair, but randomized controlled study results are lacking.

A meta-analysis (24) showed that postoperative opioid use was significantly lower in the ESPB group compared with the control group (MD -4.72, 95% CI -6.00 to -3.44, $P < .001$). The results of the present study demonstrated that the ESPB group significantly reduced motor pain VAS scores at 12 h after TAPP repair compared with the control group and that intraoperative remifentanil use, additional sufentanil use, and nalbuphine consumption at 24 h after TAPP repair were reduced in the ESPB group, which were consistent with previous studies. The incidence of adverse reactions to opioids (e.g., nausea and vomiting) was positively correlated with the dosage of opioids. By minimizing opioid use, ESPB can contribute to a reduction in these adverse effects, improving the overall patient experience.[25]

In the context of clinical significance, the observed differences in VAS scores and opioid consumption suggest a tangible impact on patient comfort and recovery. Reduced reliance on opioids not only contributes to improved pain management but also aligns with the broader goal of minimizing opioid-related adverse effects. These findings bear implications for clinical practice, emphasizing the potential role of ESPB in optimizing postoperative care and enhancing patient outcomes. Further research and larger-scale studies can provide additional insights and validate the generalizability of these results.

Boules et al.[22] revealed that the median duration of analgesia after cesarean section using 20 ml of 0.25% bupivacaine in the ESPB was 12 h.[12,16] The common methods of postoperative analgesia with nerve blocks currently used after abdominal surgery are epidural analgesia, quadratus lumborum block–and transversus abdominis plane block. Yang et al.[26,27] suggested that the use of epidural analgesia for laparoscopic colorectal surgery was associated with a prolonged hospital stay, increased hospital costs and an elevated incidence of urinary tract infections. In addition, epidural block requires high operative skills and may cause serious complications such as epidural hematoma, nerve injury and total spinal anesthesia, which limit its clinical application. Quadratus lumborum block is indicated for postoperative analgesia in abdominal, hip, and lower extremity surgery,[28] but it may lead to quadriceps muscle weakness and affect the early postoperative motor function recovery. It has been reported that transversus abdominis

plane block combined with general anesthesia provided a significant reduction in the dosage of postoperative analgesics, promoted patient recovery and shortened the length of hospital days.[29] However, the transversus abdominis plane block is subject to the risk of liver injury[30] and abdominal wall segmental motion block.[31] ESPB, as a fascial compartment block technique, provides the benefits of clear anatomy, easy differentiation under ultrasound, less peripheral vascular and nerve distribution, and a favorable block effect. It provides effective postoperative analgesia for a wide range of thoracic and abdominal procedures without disrupting the patient's early postoperative mobility.[32]

ESPB, as demonstrated in this study for TAPP repair, offers promise for enhancing postoperative pain management in a variety of abdominal surgeries, including inguinal and incisional hernia repairs, laparoscopic cholecystectomy, colorectal surgeries, and gynecological procedures. Its precision in targeting sensory nerves while sparing motor function makes it a valuable approach, potentially reducing opioid use and promoting faster patient recovery. The clear anatomical landmarks and ultrasound guidance further contribute to the effectiveness of ESPB in these surgical contexts.

The limitations of this study are: first, general anesthesia was administered immediately after the block in all patients, resulting in the unavailability of an assessment of the extent of the ESPB. Despite a VAS score of 1.96 ± 1.19 (all less than 4) at 2 h postoperative in patients with ESPB, the presence of block failure in this Group cannot yet be determined. Secondly, the optimal drug concentration for ESPB has not been firmly established. While our study utilized a 0.5% concentration of ropivacaine, the lack of a standardized optimal concentration represents a potential limitation. This uncertainty warrants further exploration in future research to refine the technique and enhance its reproducibility. It's essential to acknowledge that the small sample size in this study might limit the ability to detect less common adverse events or variations in the block's effectiveness. The generalizability of our findings to a broader population should be considered with caution. Future research endeavors with larger cohorts can provide a more robust understanding of the intervention's safety profile and efficacy, allowing for a more confident application in clinical practice.

In this study, we utilized a 0.5% concentration of ropivacaine, consistent with commonly reported clinical concentrations for ESPB (ranging from 0.2% to 0.5%)(33). However, the influence of varying ropivacaine concentrations on the extent and efficacy of the ESPB remains an area of ongoing exploration. Subsequent research efforts can play a pivotal role in advancing our understanding of ESPB by delving into various aspects. Firstly, identifying the most effective drug concentrations and volumes for ESPB represents a critical avenue for future investigation. Variables such as the specific type of local anesthetic used, the nature of the surgical procedure, and individual patient characteristics can significantly impact the block's efficacy. Fine-tuning these parameters through well-designed studies can enhance the precision and reproducibility of ESPB, ultimately contributing to optimized patient outcomes.

Furthermore, while our study has provided valuable insights into short-term postoperative pain management, the exploration of long-term impacts remains an essential direction for future research. Investigating aspects such as the duration of pain relief, functional recovery, and overall patient satisfaction over an extended postoperative period can offer a comprehensive understanding of ESPB's role in patient recovery. This longitudinal perspective is crucial for clinicians to assess the sustained benefits and potential challenges associated with ESPB, guiding informed decision-making in pain management strategies.

In conclusion, our study contributes to the growing body of evidence supporting the efficacy of ESPB in short-term postoperative pain management for abdominal surgeries. However, the journey of refining and expanding our understanding of this technique is ongoing. By addressing the nuances of drug concentrations, volumes, and long-term outcomes, future research can solidify the position of ESPB as a valuable tool in the armamentarium of pain management strategies for abdominal surgeries. The implications of our findings extend beyond the immediate postoperative period, offering a promising avenue for enhancing patient care and recovery in abdominal surgical procedures.

CONCLUSION

In summary, the findings from our study underscore the significant clinical implications of incorporating ultrasound-guided ESPB into the pain management protocol for laparoscopic TAPP repair. The reduction in motor pain, coupled with a quantifiable decrease in the need for perioperative analgesic medication and a notable decrease in the incidence of adverse effects, highlights the practical benefits of ESPB in enhancing the overall patient experience during the perioperative period.

The application of ultrasound-guided ESPB presents a promising avenue for clinical practice. By minimizing motor pain and reducing the reliance on analgesic medication, ESPB not only contributes to improved patient comfort but also offers potential cost-saving benefits for healthcare providers. These findings suggest that ESPB can be a valuable addition to the pain management toolkit, providing a more efficient and patient-friendly approach to postoperative care.

This study serves as a crucial stepping stone for future investigations, emphasizing the importance of expanding the scope of ESPB research to encompass various surgical procedures and patient populations. Further exploration is warranted to optimize the technique, determine the most effective drug concentrations, and uncover additional clinical applications. As clinicians and policymakers consider optimizing pain management protocols, our study offers tangible insights that may influence future clinical practices and guidelines. The demonstrated advantages of ultrasound-guided ESPB pave the way for its inclusion as a valuable tool in the perioperative toolkit, ultimately contributing to

improved patient outcomes and setting a precedent for enhanced pain management strategies in abdominal surgeries.

DATA AVAILABILITY STATEMENT

All data generated or analysed during this study are included in this published article.

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AUTHOR CONTRIBUTIONS

Lei Duan and Zepeng Wang contributed equally.

TRIAL REGISTRATION

This clinical trial was registered in the China Clinical Trials Center (http://www.chictr.org.cn) on 01/11/2020, with the registration number ChiCTR2000039573.

REFERENCES

1. Lavanchy JL, Buff SE, Kohler A, Candinas D, Beldi G. Long-term results of laparoscopic versus open intraperitoneal onlay mesh incisional hernia repair: a propensity score-matched analysis. *Surg Endosc*. 2019;33(1):225-233. doi:10.1007/s00464-018-6298-6
2. Bhushan S, Huang X, Su X, Luo L, Xiao Z. Ultrasound-guided erector spinae plane block for postoperative analgesia in patients after liver surgery: A systematic review and meta-analysis on randomized comparative studies. *Int J Surg*. 2022;103:106689. doi:10.1016/j.ijsu.2022.106689
3. Liheng L, Siyuan C, Zhen C, Changxue W. Erector Spinae Plane Block versus Transversus Abdominis Plane Block for Postoperative Analgesia in Abdominal Surgery: A Systematic Review and Meta-Analysis. *J Invest Surg*. 2022;35(9):1711-1722. doi:10.1080/08941939.2022.2098426
4. HerniaSurge Group. International guidelines for groin hernia management. *Hernia*. 2018;22(1):1-165. doi:10.1007/s10029-017-1668-x
5. Kingsnorth A, LeBlanc K. Hernias: inguinal and incisional. *Lancet*. 2003;362(9395):1561-1571. doi:10.1016/S0140-6736(03)14746-0
6. Huang X, Wang J, Zhang J, Kang Y, Sandeep B, Yang J. Ultrasound-guided erector spinae plane block improves analgesia after laparoscopic hepatectomy: a randomised controlled trial. *Br J Anaesth*. 2022;129(3):445-453. doi:10.1016/j.bja.2022.05.013
7. Forester B, Attaar M, Chirayil S, et al. Predictors of chronic pain after laparoscopic inguinal hernia repair. *Surgery*. 2021;169(3):586-594. doi:10.1016/j.surg.2020.07.049
8. Nikkolo C, Lepner U. Chronic pain after open inguinal hernia repair. *Postgrad Med*. 2016;128(1):69-75. doi:10.1080/00325481.2016.1121090
9. Lee S, Kim HH. Minimally invasive surgery in advanced gastric cancer. *Ann Gastroenterol Surg*. 2022;6(3):336-343. doi:10.1002/ags3.12559
10. Peery AF. Management of colonic diverticulitis. *BMJ*. 2021;372(72):n72. doi:10.1136/bmj.n72
11. Han ES, Advincula AP. Safety in Minimally Invasive Surgery. *Obstet Gynecol Clin North Am*. 2019;46(2):389-398. doi:10.1016/j.ogc.2019.01.013
12. Fiori C, Checcucci E, Amparore D, Cattaneo G, Manfredi M, Porpiglia F. Adrenal tumours: open surgery versus minimally invasive surgery. *Curr Opin Oncol*. 2020;32(1):27-34. doi:10.1097/CCO.0000000000000594
13. Löser B, Recio Ariza O, Saugel B, et al. Anesthesia for Patients Undergoing Peroral Endoscopic Myotomy Procedures: A Review of the Literature. *Anesth Analg*. 2020;130(5):1331-1340. doi:10.1213/ANE.0000000000004420
14. Forero M, Adhikary SD, Lopez H, Tsui C, Chin KJ. The Erector Spinae Plane Block: A Novel Analgesic Technique in Thoracic Neuropathic Pain. *Reg Anesth Pain Med*. 2016;41(5):621-627. doi:10.1097/AAP.0000000000000451
15. Moorthy A, Ní Eochagáin A, Dempsey E, et al. Postoperative recovery with continuous erector spinae plane block or video-assisted paravertebral block after minimally invasive thoracic surgery: a prospective, randomised controlled trial. *Br J Anaesth*. 2023;130(1):e137-e147. doi:10.1016/j.bja.2022.07.051
16. Chin KJ, Malhas L, Perlas A. The Erector Spinae Plane Block Provides Visceral Abdominal Analgesia in Bariatric Surgery: A Report of 3 Cases. *Reg Anesth Pain Med*. 2017;42(3):372-376. doi:10.1097/AAP.0000000000000581
17. De Cassai A, Tonetti T. Local anesthetic spread during erector spinae plane block. *J Clin Anesth*. 2018;48:60-61. doi:10.1016/j.jclinane.2018.05.003
18. Elsharkawy H, Ince I, Hamadnalla H, Drake RL, Tsui BCH. Cervical erector spinae plane block: a cadaver study. *Reg Anesth Pain Med*. 2020;45(7):552-556. doi:10.1136/rapm-2019-101154
19. Oh SK, Lim BG, Won YJ, Lee DK, Kim SS. Analgesic efficacy of erector spinae plane block in lumbar spine surgery: A systematic review and meta-analysis. *J Clin Anesth*. 2022;78:110647. doi:10.1016/j.jclinane.2022.110647
20. Delgado DA, Lambert BS, Boutris N, et al. Validation of Digital Visual Analog Scale Pain Scoring With a Traditional Paper-based Visual Analog Scale in Adults. *J Am Acad Orthop Surg Glob Res Rev*. 2018;2(3):e088. doi:10.5435/JAAOSGlobal-D-17-00088
21. Vidal E, Giménez H, Forero M, Fajardo M. Erector spinae plane block: A cadaver study to determine its mechanism of action. *Rev Esp Anestesiol Reanim (Engl Ed)*. 2018;65(9):514-519. doi:10.1016/j.redare.2018.09.002
22. Boules ML, Goda AS, Abdelhady MA, Abu El-Nour Abd El-Azeem SA, Hamed MA. Comparison of Analgesic Effect Between Erector Spinae Plane Block and Transversus Abdominis Plane Block After Elective Cesarean Section: A Prospective Randomized Single-Blind Controlled Study. *J Pain Res*. 2020;13:1073-1080. doi:10.2147/JPR.S253343
23. Ribeiro Junior IDV, Carvalho VH, Brito LGO. Erector spinae plane block for analgesia after cesarean delivery: a systematic review with meta-analysis. *Braz J Anesthesiol*. 2022;72(4):506-515. doi:10.1016/j.bjane.2021.09.015
24. Koo CH, Hwang JY, Shin HJ, Ryu JH. The Effects of Erector Spinae Plane Block in Terms of Postoperative Analgesia in Patients Undergoing Laparoscopic Cholecystectomy: A Meta-Analysis of Randomized Controlled Trials. *J Clin Med*. 2020;9(9):2928. doi:10.3390/jcm9092928
25. Wirz S, Schenk M, Hofbauer H, Wartenberg HC, Cascella M, Kieselbach K. [Use of rapid-onset fentanyl preparations beyond indication : A random questionnaire survey among congress participants and pain physicians]. *Schmerz*. 2021;35(2):114-123. doi:10.1007/s00482-020-00503-8
26. Yang J, Zhao M, Zhang XR, et al. Ropivacaine with Dexmedetomidine or Dexamethasone in a Thoracic Paravertebral Nerve Block Combined with an Erector Spinae Plane Block for Thoracoscopic Lobectomy Analgesia: A Randomized Controlled Trial. *Drug Des Devel Ther*. 2022;16:1561-1571. doi:10.2147/DDDT.S366428
27. Murouchi T, Iwasaki S, Yamakage M. Quadratus Lumborum Block: Analgesic Effects and Chronological Ropivacaine Concentrations After Laparoscopic Surgery. *Reg Anesth Pain Med*. 2016;41(2):146-150. doi:10.1097/AAP.0000000000000349
28. Liang J, Tian XF, Yang W. Effect of Humanistic Nursing on Preoperative Anxiety, Postoperative Pain Relief and Prognosis of Colorectal Cancer Patients. *J Mod Nurs Pract Res*. 2021;1(2):9. doi:10.53964/jmnpr.2021009
29. Kıtlık A, Erdogan MA, Ozgul U, et al. Ultrasound-guided transversus abdominis plane block for postoperative analgesia in living liver donors: A prospective, randomized, double-blinded clinical trial. *J Clin Anesth*. 2017;37:103-107. doi:10.1016/j.jclinane.2016.12.018
30. Krishnan S, Cascella M. Erector Spinae Plane Block. 2023 June 4. In: *StatPearls*. [Internet] StatPearls Publishing; 2023.
31. Warner M, Yeap YL, Rigueiro G, Zhang P, Kasper K. Erector spinae plane block versus transversus abdominis plane block in laparoscopic hysterectomy. *Pain Manag (Lond)*. 2022;12(8):907-916. doi:10.2217/pmt-2022-0037
32. Shim JG, Ryu KH, Kim PO, et al. Evaluation of ultrasound-guided erector spinae plane block for postoperative management of video-assisted thoracoscopic surgery: a prospective, randomized, controlled clinical trial. *J Thorac Dis*. 2020;12(8):4174-4182. doi:10.21037/jtd-20-689
33. Macaire P, Ho N, Nguyen V, et al. Bilateral ultrasound-guided thoracic erector spinae plane blocks using a programmed intermittent bolus improve opioid-sparing postoperative analgesia in pediatric patients after open cardiac surgery: a randomized, double-blind, placebo-controlled trial. *Reg Anesth Pain Med*. 2020;45(10):805-812. doi:10.1136/rapm-2020-101496