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Research article

Ultrasound-guided erector spinae plane block for perioperative analgesia in patients undergoing laparoscopic nephrectomy surgery: A randomized controlled trial

Ming Yang, Lei Cao, Tong Lu, Cheng Xiao, Zhuoxi Wu, Xuetao Jiang, Wei Wang, Hong Li *

Department of Anesthesiology, Xinqiao Hospital of Chongqing, Second Affiliated Hospital of Army Medical University, PLA, Chongqing, 400037, China

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ABSTRACT

Study objective: Kidney neoplasms have a high incidence, and radical nephrectomy or partial nephrectomy are the main treatment options. Our study aims to investigate the use of ultrasound-guided erector spinae plane block for perioperative analgesia in patients undergoing laparoscopic nephrectomy surgery.
Design: Prospective, randomized, double-blind.
Setting: University hospital.
Patients: Our study included 50 patients (ASA I-III) who underwent laparoscopic nephrectomy at the hospital of Second Affiliated Hospital of Army Medical University.
Interventions: The patients were divided into two groups: the ESPB group and the control group. In the ESPB group, a mixture of 10 mL of 1% lidocaine, 10 mL of 0.7% ropivacaine, 0.5 μg/kg dexmedetomidine, and 5 mg of dexamethasone was administered. In the control group, 20 mL of 0.9% saline was administered.
Measurements: The primary outcome measure was the total consumption of sufentanil during the intraoperative period. Secondary outcome measures included visual analogue scale (VAS) pain scores at rest and during coughing at 1 h, 6 h, 12 h, 24 h, and 48 h postoperatively, intraoperative consumption of remifentanil, frequency of rescue analgesic administration, consumption of rescue analgesia and incidence of postoperative nausea and vomiting within 48 h.
Results: The ESPB group exhibited lower intraoperative consumption of sufentanil, lower consumption of rescue analgesia, as well as VAS scores at rest and during coughing within the first 24 h postoperatively, compared to the control group. However, no significant differences were observed in VAS scores at 48 h postoperatively, postoperative nausea and vomiting, or the need for postoperative rescue analgesia.
Conclusions: Ultrasound-guided ESPB performed in patients who underwent laparoscopic nephrectomy demonstrated a substantial decrease in intraoperative opioid consumption, as well as lower VAS scores at rest and during coughing in the postoperative period.

* Corresponding author.
E-mail address: damingshen0930@163.com (H. Li).

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1. Introduction

Kidney neoplasms are among the most frequently diagnosed malignancies [1]. The global incidence of kidney neoplasms is on the rise [2]. Radical nephrectomies and nephron sparing surgery are the established surgical approaches for patients with kidney neoplasms according to tumor characteristics , patient preferences, comorbidities and physician experience [3]. With the development of minimally invasive surgery, laparoscopic and robotic-assisted techniques have become widely utilized in renal tumor surgery. Minimally invasive surgery has been associated with lower levels of postoperative pain compared to open surgery [4]. Nonetheless, abdominal incisional pain remains a significant concern in postoperative pain management. Simultaneously, the concept of Enhanced Recovery After Surgery (ERAS) has gained popularity in perioperative management.

Postoperative analgesia plays a central role in ERAS. Therefore, multimodal analgesic regimens, including multiple analgesics and nerve block methods, are recommended. Erector spinae plane (ESP) block is a relatively new technique introduced by Forero et al., in 2016 [5]. ESP block has shown promising results in reducing postoperative pain [6,7]. The proposed mechanisms of action include the spread of LAs to paravertebral space, systemic absorption of local anesthetics (LAs) , thoracolumbar fascial innervation mediated analgesia and immunomodulatory effects of LAs [7,8]. However, there is a scarcity of clinical trials investigating the use of ESP block for postoperative pain management in nephrectomies.

The addition of adjuvants to local anesthetics has been investigated to enhance the quality and duration of nerve blockade. Dexamethasone and dexmedetomidine are two adjuvants that have gained attention for their potential benefits in peripheral nerve blocks. Dexamethasone, a corticosteroid, has been shown to prolong the duration of nerve blockade, reduce postoperative pain, and decrease the need for additional analgesics [9]. Dexmedetomidine, an α2-adrenergic agonist, has demonstrated similar effects, including prolonged nerve blockade, improved postoperative analgesia, reduced rescue analgesic requirements, and decreased incidence of postoperative nausea and vomiting [10].

Given the positive outcomes observed in previous studies, the objective of our study was to evaluate the effectiveness of using dexamethasone and dexmedetomidine as adjuvants in ultrasound-guided ESP block for perioperative analgesia in patients undergoing laparoscopic nephrectomies.

2. Materials and methods

2.1. Study design

This prospective, randomized, controlled trial was conducted at a single center and received approval from the Medical Ethics Committee of Second Affiliated Hospital of Army Medical University, PLA with the approval number 2023-yandi034-01. The trial was also pre-registered at Chinese Clinical Trial Registry with the reference number ChiCTR2300068578 on February 2023. Prior to enrollment, written informed consent was obtained from all participants between February 20, 2023 and February 20, 2024. The study was funded by the National Natural Science Foundation of China.

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2.2. Study population, blinding, and randomization

The study included patients aged 18–65 years with American Society of Anesthesiologists (ASA) physical status I-III, who were scheduled for laparoscopic nephrectomies under general anesthesia. Exclusion criteria encompassed the absence of written consent, allergy to local anesthetics, BMI >35 kg/m^2, history of opioid or alcohol abuse, existing chronic pain conditions, history of mental illness or taking psychotropic drugs, severe spinal deformity, long-term use of analgesics or sedatives, severe renal insufficiency (clearance less than 30 mL/min) and severe hepatic insufficiency.

A total of 50 eligible patients were enrolled in the study and randomly assigned to either the ultrasound-guided erector spinae plane block (ESPB) group or the control group at a 1:1 ratio using a computerized random-number generator. The randomization process was conducted by an independent individual not involved in the study. Patient codes were placed in closed, opaque envelopes, and the random sequence was concealed from the researchers. The codes were only opened for data analysis during the follow-up period. The ESPB procedure was performed prior to the induction of general anesthesia. The anesthesiologist performing the procedure was aware of the group assignment and thus not blinded to it.

2.3. Regional anesthesia block procedures

The procedure was conducted prior to the induction of general anesthesia, following the administration of 2 mg midazolam. Patients were positioned laterally under sterile conditions. A high-frequency linear array probe (UMT-400, Mindray, China) and a 21-gauge (21G) nerve block needle (AN-NO.7X90, MEIXING, China) were utilized for the procedure.

2.4. Ultrasound-guided ESPB

After positioning the patients laterally, the linear probe was used to identify the thoracic 8 (T8) and T11 spinous processes along the midline of the spine. Subsequently, the ultrasound probe was moved laterally by 2–3 cm to locate the hyperechogenicity of the T8 transverse process. The T8 transverse process and erector spinae muscle were then visualized. Using the in-plane technique, a 21G

needle was advanced in a cranio-caudal direction until the needle tip reached the tip of the T8 transverse process (Fig. 2A and B). The correct position of the needle tip was confirmed by hydrodissection of the interfascial plane using 2–3 ml of 0.9% normal saline. Under ultrasound guidance, a mixture of 10 mL of 1% lidocaine, 10 mL of 0.7% ropivacaine, 0.5 μg/kg dexmedetomidine, and 5 mg of dexamethasone was observed in real-time.

2.5. Anesthesia management

Routine monitoring was conducted upon the patients' transfer to the operating room. Depth of anesthesia monitoring was consistently employed for all patients. The subjects were induced with propofol (1.5–2.5 mg/kg) and sufentanil (0.3–0.4 μg/kg) as per standard procedure. Tracheal intubation was performed after the patients lost consciousness, following the administration of rocuronium (0.6 mg/kg). General anesthesia was maintained using propofol (2–4 mg/kg), remifentanil (0.1–0.2 μg/kg/min), and sevoflurane (1–2%) to achieve a targeted depth of anesthesia between 40 and 60 BIS. All patients received fluid infusion of 5–7 ml/kg (ringer acetate or compound electrolytes and solution). The infusion rate of remifentanil was adjusted to ensure that patients' arterial blood pressure and heart rate did not deviate by more than 20% from baseline values. After adjusting the remifentanil dosage, if blood pressure remains uncontrolled, an additional 0.1 μg/kg of sufentanil will be administered. Volume-control ventilation was employed for intraoperative ventilation management. The ventilation parameters were set as follows: tidal volume (6–8 ml/kg, based on ideal body weight), I:E ratio (1:2), respiratory rate (12–14 bpm), positive end-expiratory pressure (PEEP 5–8 cmH2O), and fraction of inspired oxygen (0.40). The goal of ventilation was to maintain end-tidal carbon dioxide levels between 35 and 45 mmHg by adjusting the respiratory rate while keeping the driving pressure below 20. Tropisetron (5 mg, i.v.) was routinely administered half an hour before the end of surgery to prevent nausea and vomiting. After the completion of surgery, all patients were transferred to the post-anesthesia care unit (PACU) and extubated once they met the extubation criteria.

2.6. Analgesia management and rescue analgesic

Upon the patient's transfer to the Post-Anesthesia Care Unit (PACU), a transvenous patient-controlled analgesia (PCA) pump would be initiated. Pain assessment was conducted by an anesthesia nurse using the visual analogue scale (VAS) 10 min after extubation. Dezocine (5 mg i.v.) was administered as rescue analgesia for pain scores >3/10 at rest or during coughing. Pain reassessment was performed 10 min after each dose. If the pain score remained above 3/10, an additional dose of Dezocine (5 mg i.v.) was administered. The PCA pump was prepared with a formulation of 3 μg/kg sufentanil, 0.5 μg/kg dexmedetomidine, and 5 mg tropisetron diluted to 200 ml with 0.9% saline. The parameters for the analgesia pump were as follows: a loading dose of 2 ml, a background infusion rate of 4 ml/h, a bolus dose of 2 ml, and a lockout time of 15 min. All patients were educated on how to use the PCA pump.

2.7. Outcomes

The primary outcome measure was the total consumption of sufentanil during the intraoperative period. Secondary outcome measures included visual analogue scale (VAS) pain scores at rest and during coughing at 1 h, 6 h, 12 h, 24 h, and 48 h postoperatively, intraoperative consumption of remifentanil, frequency of rescue analgesic administration, and incidence of postoperative nausea and vomiting within 48 h.

2.8. Data collection

Postoperative pain was assessed using the visual analogue scale (VAS). VAS pain scores at rest and during coughing were recorded at 1 h, 6 h, 12 h, 24 h, and 48 h after surgery. The VAS scale ranged from 0 to 10, with the following interpretations: 0 for no pain, 1–3 for mild pain, 4–6 for moderate pain, 7–9 for severe pain, and 10 for unbearable severe pain. Data regarding the total consumption of sufentanil during the intraoperative period, intraoperative remifentanil usage, frequency of rescue analgesic administration, and incidence of postoperative nausea and vomiting were documented. Postoperative nausea and vomiting were assessed using a 4-stage verbal descriptive scale (0 = none, 1 = mild nausea not requiring treatment, 2 = moderate nausea and vomiting requiring treatment, 3 = severe nausea and vomiting not responding well to treatment) [11].

2.9. Sample size calculation and statistical analysis

We used the total amount of sufentanil during intraoperative period in the two groups (ESPB group: 32.5 ± 5.3, Control group: 38 ± 5.2) in the pre-test (10 patients each group) to assess the sample size. The Medsci software was used. Considering 20% data loss , a sample size of 25 per group will have 90% power to detect a statistically significant difference, with a type 1 error set as 0.05.

All data were performed with SPSS software version 26.0 (IBM, New York, USA). A P value < 0.05 was considered statistically significant. All normally distributed continuous variables were expressed as mean ± standard deviation and were analyzed with a Student's *t*-test, and a Mann-Whitney *U* test for non-normally distributed data. Categorical variables were described with frequencies (%) and compared with chi-square test or Fisher's exact test.

3. Result

Between February 20, 2023 and February 20, 2024, a total of 50 eligible patients were included in the study, with 25 patients in the ESPB group and 25 patients in the control group. Two patients from each group were excluded from the final analysis, as shown in Fig. 1. Baseline characteristics such as age, sex, body mass index (BMI), and American Society of Anesthesiologists Physical Status Classification (ASA) were similar between the two groups, as presented in Table 1.

The intraoperative characteristics are summarized in Table 2. There was no significant difference in surgery time between the ESPB group and the control group (169 min vs 153 min, $p = 0.23$). However, the intraoperative consumption of sufentanil was lower in the ESPB group compared to the control group (39.13 vs 45.43, $p = 0.002$). Similarly, the consumption of intraoperative remifentanil was also lower in the ESPB group compared to the control group (662.65 vs 802.52, $p = 0.049$).

During the postoperative assessments at various time points, both VASrest and VAScough scores were illustrated in Fig. 3. Significantly lower VASrest scores were observed in the ESPB group compared to the control group at 1 h, 6 h, 12 h, and 24 h ($p = 0.023$, $p = 0.009$, $p = 0.023$, $p = 0.004$, respectively). Similarly, VAScough scores were also lower in the ESPB group compared to the control group at 1 h, 6 h, 12 h, and 24 h ($p = 0.024$, $p = 0.014$, $p = 0.017$, $p = 0.009$, respectively). However, there were no significant differences in VAS scores between the two groups at 48 h ($p = 0.81$, $p = 1$).

The incidence of nausea and vomiting did not show statistically significant differences between the ESPB group and the control group ($p = 0.247$). Additionally, rescue medication consumption and the frequency of rescue administration were comparable between the two groups ($p = 0.22$; $p = 0.56$) (Table 3).

4. Discussion

The present clinical trial demonstrates that a single preoperative ultrasound-guided erector spinae plane block (ESPB) resulted in reduced intraoperative consumption of sufentanil and lower postoperative rescue analgesia consumption. Additionally, it was associated with lower Visual Analog Scale (VAS) scores at postoperative 1h, 6h, 12h and 24h. However, there were no statistically significant differences observed in postoperative 48h VAS scores, and the incidence of nausea and vomiting.

ESPB, being one of the well-established fascial plane blocks, has gained significant attention due to its wide applicability, simplicity, and safety. It has been utilized for acute and chronic pain management, as well as an adjunctive analgesic in various surgical procedures such as thoracic surgery, cardiac surgery, and abdominal surgery [12–14]. Despite its popularity, the exact mechanism of

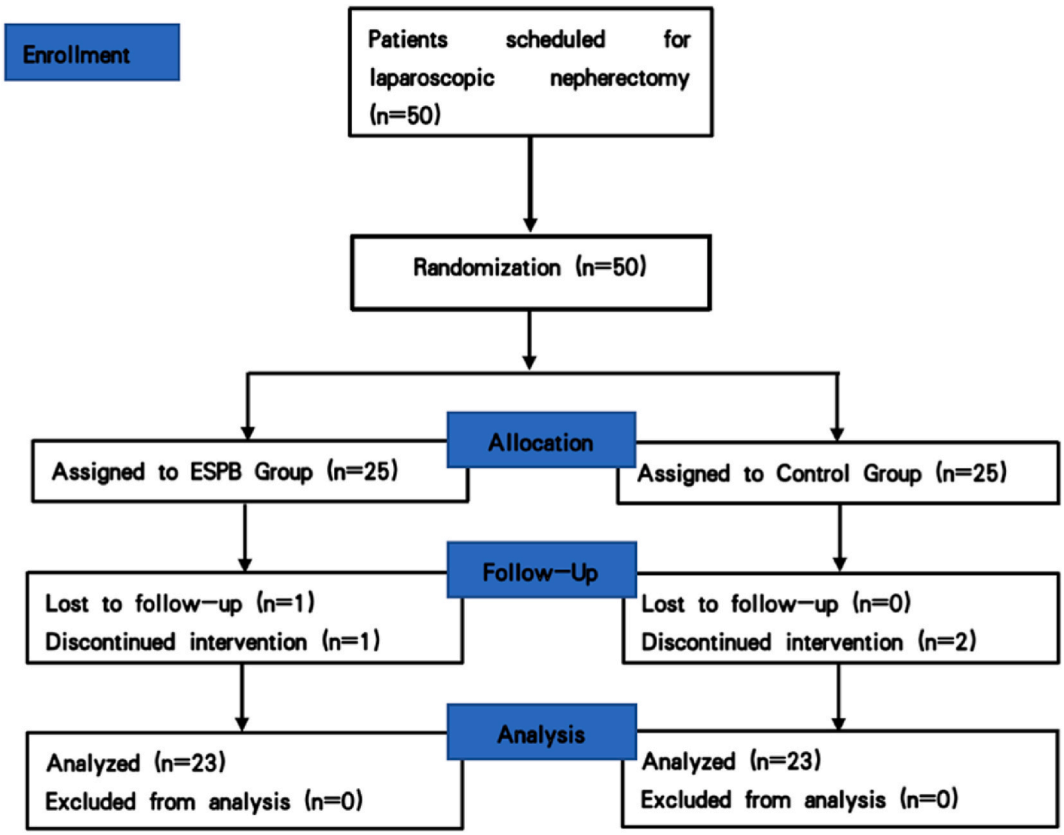

Fig. 1. Flowchart.

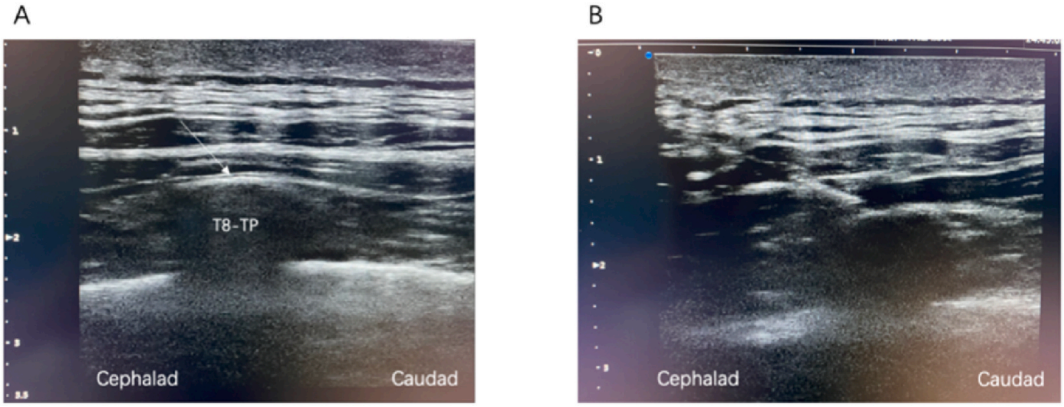

Fig. 2. A-B procure of Ultrasound-guided ESPB. (A) Relevant anatomy of ESPB, the white arrow represents the injection site.(B) Ultrasound-guided ESPB. Local anesthetic is injected with a block needle into the interfacial plane between erector spinae muscle and T8-TP.
ESPB erector spinae block; T8-TP, therocic 8 transverse process.

Table 1
Patient baseline demographics.

	ESPB Group	Control Group	*p*-Value
	N = 23	N = 23	
Age (years)	52.08 ± 7.65	50.30 ± 8.59	0.461
BMI (kg/m^2)	24.58 ± 3.13	22.95 ± 2.78	0.069
ASA I/II/III, n	2/20/1	1/21/1	
Sex (male/female)	14/9	11/12	0.375

Note. Data are expressed as mean ± standard deviation or number (n). Abbreviation: *ASA*, American Society of Anesthesiologists; *BMI,* body mass index.

Table 2
Intraoperative demographics.

	ESPB Group	Control Group	*p*-Value
	N = 23	N = 23	
Surgery time	169 ± 42	153 ± 44	0.23
Intraoperative consumption of sufentanil (ug)	39.13 ± 7.01	45.43 ± 6.20	0.002**
Intraoperative consumption of remifentanil (ug)	662.65 ± 261.13	802.52 ± 202.92	0.049

Data are expressed as mean ± standard deviation. ESPB, erector spinae plane block.
** means $p < 0.01$.

action of ESPB remains elusive, leading to differing opinions on its mode of action. The most contentious aspect revolves around whether ESPB primarily spreads in the paravertebral space. Findings from cadaveric studies and in vivo observations have yielded inconsistent results. Cadaveric studies have predominantly associated ESPB with fascial spreading in the back muscles, with limited diffusion into the paravertebral space [15]. In contrast, magnetic resonance imaging (MRI) studies involving the injection of 30 ml of local anesthetics at the T10 level demonstrated consistent spread to the erector spinae muscles, neural foramina, and intercostal space, resulting in sensory blockage of both ventral and dorsal dermatomes [16]. These differences may be due to the changes in temperature, respiratory status, anatomical changes including muscles, skeleton, vascular and fascia.

Currently, minimally invasive surgery has become the standard approach for kidney procedures. However, postoperative pain following these procedures can range from moderate to severe, leading to potential overuse of opioids during the perioperative period. A prospective observational study revealed that 60% of prescribed opioids went unused in patients undergoing major prostate and kidney operations [17]. The predominant location of kidney pain corresponds to the dermatomes of T10-L2, making anesthetic blocks a viable option for effective analgesia. Wesley et al. observed a significant reduction in opioid consumption on postoperative days in patients who underwent robotic-assisted laparoscopic partial or radical nephrectomies, with the use of a quadratus lumborum block providing sensory blockade between T6-7 and L1-2 [18]. Similar results were reported in case reports involving open urological procedures [19]. More recently, a case report demonstrated the efficacy of ESPB at the T9 level during open partial nephrectomy, resulting in a substantial reduction in opioid use and improved intraoperative management [20]. After considering various factors, we made the decision to administer an ESPB at the T8 level in our trial.

It is crucial to thoroughly evaluate the effectiveness of ESPB before incorporating it as a routine clinical practice. Numerous studies

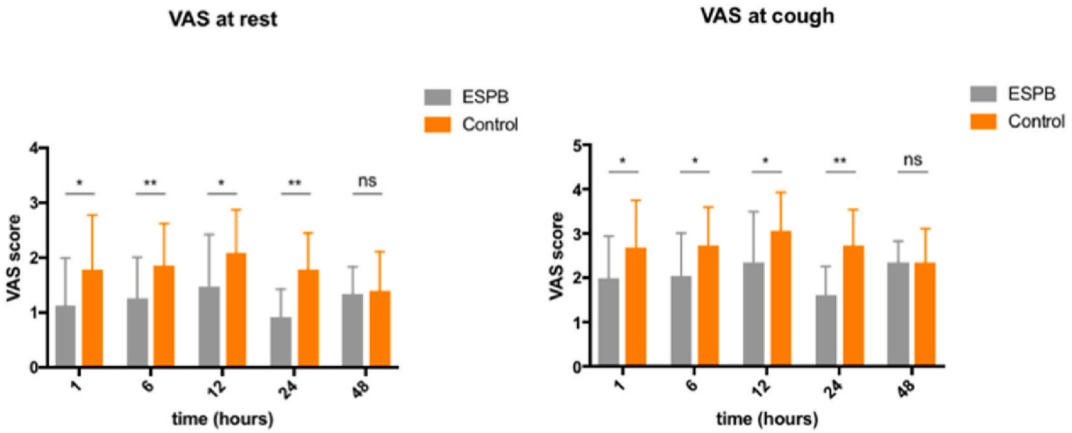

Fig. 3. VAS scores at rest and cough between ESPB group and Control group at different points times. Data are expressed as mean ± standard deviation VAS, visual analogue scale; ESPB, erector spinae plane block.
*p < 0.05 vs. corresponding data of the ESPB and Control group.
**p < 0.01 vs. corresponding data of the ESPB and Control group.
ns, nonsense vs. corresponding data of the ESPB and Control group.

Table 3
Postoperative rescue analgesia and complications.

	ESPB Group	Control Group	*p*-Value
	N = 23	N = 23	
Rescue consumption of tropisetron (mg)	4.17 ± 4.18	4.13 ± 4.92	0.03
Times of rescue	8.78 ± 4.34	7.95 ± 5.12	0.56
Nausea and vomit	0.17 ± 0.49	0.04 ± 0.21	0.247

have provided evidence supporting the efficacy of ESPB. For instance, a recent prospective study demonstrated that ultrasound-guided ESPB yielded similar effects to thoracic paravertebral nerve block (TPVB) in terms of reducing intraoperative sufentanil consumption, shortening anesthesia awakening time and extubation time, and decreasing VAS scores at rest and during coughing at 1, 6, and 12 h post thoracoscopic pulmonary lobectomy [13]. In accordance with our data, we observed a significant reduction in intraoperative consumption of sufentanil, as well as lower VAS scores at rest and during coughing at 1, 6, 12, and 24 h postoperatively. Another randomized comparative trial also revealed that ESPB resulted in lower VAS scores compared to transversus abdominis plane block during the first 24 h after surgery [14]. Similarly, Tulgar et al. observed reduced pain scores and decreased analgesic requirements following a single-shot ESPB in laparoscopic cholecystectomy [6]. However, Shanthanna et al. found no superiority of ESP block over peri-articular injection in terms of pain control, opioid use, or patient satisfaction in arthroscopic shoulder surgery [11]. Nevertheless, they did observe lower postoperative opioid use with ESPB. In our study, we observed lower postoperative rescue analgesia consumption in ESPB group.

It has been reported that the addition of dexamethasone and dexmedetomidine as adjuncts can extend the duration of nerve blocks. Therefore, we incorporated dexamethasone and dexmedetomidine into our procedure. Previous research conducted by Vorobeichik et al. demonstrated that dexmedetomidine administration could significantly prolong the duration of analgesia [10]. Their meta-analysis even suggested an optimal dose range of 50-60ug for nerve blocks. Additionally, a randomized trial investigating perineural dexamethasone as an adjunct found that it extended the duration of ulnar nerve block by 1 h compared to placebo [21]. These findings support the use of dexamethasone and dexmedetomidine as adjuncts to enhance the duration of nerve blocks. The inclusion of dexamethasone and dexmedetomidine in the nerve block may enhance its efficacy and provide additional pain relief, but their direct impact on the duration of the block is limited.

The study suggests that ESPB can effectively reduce opioid consumption and postoperative pain in laparoscopic nephrectomy patients. The strengths of our study are rooted in the innovative use of erector spinae plane block (ESPB) within the context of laparoscopic nephrectomy. Notably, our study provides compelling evidence that ESPB is a highly effective technique for providing analgesia during these surgeries. This finding has significant implications for the future of clinical practice and perioperative care , which may offering a promising path for the future of anesthesia and perioperative management.

4.1. Limitation

Several limitations should be acknowledged in our work. Firstly, it is important to note that the findings are derived from a single center, which may limit the generalizability of the results. Future prospective studies conducted across multiple centers are warranted

to validate whether this technique can be incorporated into clinical practice as a routine schedule. Secondly, as the injection volume plays a crucial role in fascial plane blocks, it would be advantageous to explore various groups with different dose distributions in ESPB to determine the optimal dosage. Thirdly, the study did not include a sensory block test, which is considered a relevant method for evaluating neural blockade in regional anesthesia. Cutaneous sensory testing is particularly valuable in this regard. Additionally, the expansion of LAs was not assessed in our study. Investigating the prolonged duration of ESPB, specifically whether it is influenced by dexamethasone, dexmedetomidine, or both, is an area that should be explored in future research.

5. Conclusion

Ultrasound-guided ESPB performed in patients who underwent laparoscopic nephrectomy demonstrated a substantial decrease in intraoperative opioid consumption, as well as lower Visual Analog Scale (VAS) scores at rest and during coughing in the postoperative period.

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Data availability statement

The data generated or analyzed during this study are available from the corresponding author upon request.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Ming Yang: Writing – original draft, Investigation. **Lei Cao:** Data curation. **Tong Lu:** Data curation. **Cheng Xiao:** Project administration. **Zhuoxi Wu:** Supervision, Software, Formal analysis. **Xuetao Jiang:** Visualization, Investigation. **Wei Wang:** Project administration, Methodology. **Hong Li:** Writing – review & editing, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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