

# Ultrasound-guided single erector spinae plane block versus thoracic paravertebral block for patients undergoing video-assisted thoracoscopic lobectomy: a single center randomized controlled trial

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## Research article

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# Abstract

**Background:** Whether ultrasound-guided erector spinae plane block (ESPB) can replace thoracic paravertebral block (TPVB) remains unknown. This study aimed to determine the efficacy of ESPB compared with TPVB for postoperative analgesia after video-assisted thoracoscopic lobectomy under general anesthesia. **Methods:** This prospective randomized controlled trial divided patients into a control group, a TPVB group (0.3 mL/kg, 0.5% ropivacaine), and an ESPB group (0.5 mL/kg, 0.5% ropivacaine). Dermatomes with loss of pinprick sensation, were recorded during 30 min after block administration. Visual analog scale (VAS) scores, total analgesic dose, and complications after surgery were recorded. **Results:** Whether at rest or during coughing, the VAS scores were lower in ESPB group at 1, 6, 18, 24, and 48 h after surgery compared with the Control group. VAS scores were similar in the ESPB and TPVB groups at 1 h, but were lower in the ESPB group at 6, 18, 24, and 48 h postoperatively. **Conclusions:** Single ESPB provided superior postoperative analgesia than TPVB, without causing any adverse effect.

## Background

Thoracic surgery is considered to be one of the most painful surgical procedures. Pain after thoracic surgery can lead to delayed recovery and increase the incidence of complications such as atelectasis and pulmonary infections due to ineffective breathing and clearing of secretions. Effective pain management may reduce these complications and the risk of chronic pain[1-3].

Thoracic epidural analgesia (TEA) and thoracic paravertebral block (TPVB) are widely used for postoperative analgesia after thoracotomy. However, these procedures are technically challenging and associated with high failure rates[4]. TEA is associated with complications such as spinal cord trauma, epidural hematoma, hypotension, and respiratory depression[5], while TPVB is associated with a risk of spinal cord trauma, and pneumothorax[6]. There has been a recent effort to increase the use of ultrasound guidance when conducting TEA or TPVB, it reduced the failure rate and complications, but it is still technical challenges for a less skilled anesthesiologist.

Ultrasound-guided single erector spinae plane block (ESPB) was first reported by Forero et al. in 2016[7]. ESPB may be technically simpler and safer than TPVB, because the transverse process act as a clear target for the injection, and acts as an anatomical barrier to avoids critical structures injury, such as pleura and spinal cord[8, 9]. ESPB has been reported by many case reports that it can produce cutaneous sensory block, indicating that both the ventral and dorsal spinal rami were anesthetized[10, 11], even can produce visceral analgesia by blocking the sympathetic chain[12, 13]. This raises the question of whether the ESPB can serve as a technically simpler alternative to TPVB with a similar analgesic effect

We hypothesized that ESPB is as effective as TPVB for relieving acute pain in patients undergoing video-assisted thoracoscopic lobectomy. The primary outcomes of the study were the postoperative visual analog scale (VAS) for pain under the status of rest and cough at 1, 6, 18, 24, and 48 h after surgery. The secondary outcomes were comparisons of the number of anesthetized dermatomes, the intraoperative

remifentanyl dosage, the doses of postoperative patient-controlled analgesia and rescue analgesia, the incidence of adverse effects, such as pneumothorax, local anesthetic intoxication, nausea and vomiting.

## Methods

### Patients and study design

This prospective randomized controlled study was approved by the ethics committee of Beijing Chaoyang Hospital (2017-ke-81) and registered with the Clinical Trial Registry of China (ChiCTR-INR-17011499). The study took place at the Department of Anesthesiology, Beijing Chaoyang Hospital, Capital Medical University, Beijing, from Jun 1, 2017, to May 30, 2018. All patients provided written informed consent before being enrolled into the study.

Patients suffering from lung cancer were eligible for enrollment in this study if they were between 20 and 70 years of age, were scheduled to undergo video-assisted thoracoscopic lobectomy for a single lobe and systematic lymphadenectomy, and had an American Society of Anesthesiologists (ASA) class of I or II. Patients with local infection, coagulopathy, allergy to local anesthetics, obesity (body mass index > 30 kg/m<sup>2</sup>), decreased pulmonary reserve, major cardiac disorders, liver and renal dysfunction, pre-existing neurological deficits, or psychiatric illness were excluded.

### Randomization and blinding

The patients were randomized using sequential sealed envelopes prepared by an independent statistician using a computer-generated random number table. Patients were randomly allocated to an ESPB group, a TPVB group, and a control group using computer-generated random numbers. Patients in the control group did not receive any regional block, and patients in ESPB and TPVB groups received the corresponding blocks. The postoperative assessors were blinded to grouping.

### Procedures

Both ESPB and TPVB were performed at level T5 with patients in lateral position, with affected side upward, under ultrasound guidance with a Navi Series ultrasound device (Wisonic Medical Technology Co. Ltd., Shenzhen, China) equipped with a linear ultrasound transducer (4–15 MHz). A 22G 90-mm needle (TuoRen Medical Instrument Finty Company, Zhengzhou, China) with a 18° sharp tip was chosen for both blocks.

In the ESPB group, the transducer was placed 2–3 cm from the midline in a sagittal orientation. After the T5 transverse processes and the erector spinae muscle had been identified, the needle was inserted laterally to medially with out-plane technique until close contact was made with the transverse process,

without air or blood aspiration, 0.5 mL/kg (but no more than 40 ml) of 0.5% ropivacaine was administered. And we could see the liquid spreading between the transverse process and the erector spinae muscle.

In the TPVB group, the transducer was placed 2–3 cm lateral to the midline in a vertical orientation. Once the T5 transverse process, internal intercostal membrane and parietal pleura had been identified, the needle was inserted laterally to medially with in-plane technique until the tip lay in the thoracic paravertebral space beyond the internal intercostal membrane. 2ml normal saline was injected to confirm the pressing of the parietal pleura, 0.3 mL/kg of 0.5% ropivacaine was administered for the block.

Starting from 30 min after block administration, pinprick sensation in the T1–T12 dermatomal distribution was monitored every 5 min by an independent observer who was blinded to the study group. After confirming sensory loss, general anesthesia was induced with midazolam 0.02 mg/kg, sufentanyl 0.3–0.4 µg/kg, and propofol 1.5–2 mg/kg. Rocuronium bromide 0.8 mg/kg was administered to facilitate tracheal intubation. The trochal ports were made at the 7th and 8th intercostal levels along the midaxillary line. Anesthesia was maintained with propofol and remifentanyl, and the dosage was adjusted according to the hemodynamic parameters and bispectral index. Additional boluses of intravenous rocuronium bromide were given as required. A chest drain to be placed for at least 48 hours after surgery was inserted before the skin closure at the 7th and 8th intercostal levels. During the 10 min before the end of the operation, only tramadol 100 mg was used for analgesia. The intraoperative remifentanyl dosages were recorded. Non-steroidal anti-inflammatory drugs were not used during the operation.

Postoperative analgesia via a patient-controlled intravenous analgesia (PCIA) device was initiated immediately after the surgery and continued until 48 h after the surgery. The PCIA device contained 100 µg sufentanyl and 10 mg tropisetron diluted with normal saline to a volume of 100 mL. The device was set up to administer a background dose of 1 mL/h and a bolus dose of 2 mL with a 15-min lockout interval. Before the operation, patients were taught how to use the PCIA device to manage their pain and the visual analog scale (VAS) to score their pain. If the PCIA device could not meet a patient's analgesic demand, and the VAS score at rest was 4 or more, 50 mg flurbiprofen axetil was intravenously administered as rescue analgesia.

An investigator blinded to the group allocation recorded the VAS scores at rest and during coughing at 1, 6, 18, 24, and 48 h after the operation. The number of doses administered via the PCIA device, the total volume of analgesic drugs administered via the PCIA device, the doses of flurbiprofen axetil administered, and the incidence of pneumothorax, local anesthetic intoxication, postoperative nausea and vomiting after the surgery were noted.

## Sample size calculation

As the primary outcome of this study was the the VAS scores postoperatively, we took the VAS scores at rest 18h post-surgery for example. According to the preliminary study (n=10, unpublished data), the mean VAS scores after ESPB and TPVB was 2.1 and 3.6, respectively, and the SD of the VAS scores was 1.6. We defined an acceptable superiority margin as 1, according to the previous study[14]. A sample size of 7 in each group was required to provide a power of 0.8 and a one-sided  $\alpha$  of 0.05, given the possibility of missed follow-up rate 10%.

## Statistical analysis

Statistical analysis was performed using GraphPad Prism 7 software. Numerical data were expressed as mean and standard deviation or median and range, as appropriate. Qualitative data were expressed as frequency and percentage. Qualitative parameters were analyzed using the chi-square test or Fisher exact test. One-way analysis of variance (ANOVA), followed by Holm-Sidak's multiple comparisons, was used to compare the quantitative parameters between groups.  $P < 0.05$  was considered statistically significant.

# Results

## General information

A total of 81 patients were possibly eligible for enrollment into the study. Of these, 3 patients did not meet the selection criteria, and 11 patients did not consent to participate in the study. The remaining 67 patients were enrolled in the present study, and were randomly allocated to the three study groups. The block could not be performed in a patient because of a big lipoma at the puncture site, 1 patient refused to participate in the study before anesthesia..Additionally, 2 patients required conversion to open thoracic surgery, 1 patient suffered severe allergic reaction during the operation, 2 patients developed hemorrhage. Therefore, 60 patients were included in our final analysis. Of these, 19 patients were randomized to the control group, 20 patients were randomized to the TPVB group, and 21 patients were randomized to the ESPB group. A flowchart of patient selection and the study procedures has been presented in Figure 1. Patients in each of the three groups were comparable with regards to age, sex, body mass index, ASA status, and duration of surgery (Table 1).

## Outcomes

At 30 min after block administration, pinprick sensation was absent in 5.4 (1.2) dermatomes (T2–T8) in the ESPB group and 4.5 (1.1) dermatomes (T3–T7) in the TPVB group.

The dosages of remifentanil used in the operation in ESPB and TPVB groups were significantly lower than that in the control group (ESPB vs Control,  $P < 0.001$ ; TPVB vs Control,  $P < 0.001$ ). There were no

statistically significant differences in the amount of remifentanyl between ESPB and TPVB groups ( $P=0.34$ ). (Fig. 2)

At 1, 6, 18, 24 and 48h after the surgery, the VAS scores at rest and during coughing were significantly lower in the ESPB group than in the control group (rest: all time points,  $P<0.001$ ; cough: 1h, 6h and 18h,  $P<0.001$ ; 24h,  $P=0.014$ , 48h,  $P=0.005$ ); The VAS scores at rest and during coughing did not differ between the ESPB and TPVB groups at 1 h postoperatively (rest:  $P=0.690$ , cough:  $P=0.376$ ); however, at 6, 18, 24, and 48 h, these scores were significantly lower in the ESPB group than in the TPVB group (rest: 6h,  $P=0.009$ , 18h,  $P<0.001$ , 24h,  $P<0.001$ , 48h,  $P<0.001$ ; cough: 6h,  $P<0.001$ , 18h,  $P<0.001$ , 24h,  $P=0.016$ , 48h,  $P=0.002$ ). (Fig. 3 and 4).

The number of PCIA doses delivered, the volume of analgesic drugs administered via the PCIA device were significantly lower in the TPVB and ESPB groups than in the control group ( $P<0.001$ ), and were lower in the ESPB group than in the TPVB group ( $P<0.001$ ) ( Fig. 5and 6). The consumption of flurbiprofen axetil were significantly lower in the TPVB and ESPB groups than in the control group (0-48h: TPVB vs Control,  $P = 0.019$ ; ESPB vs Control,  $P<0.001$ ), and were lower in the ESPB group than in the TPVB group (0-48h:  $P=0.019$ ) (Fig. 7).

Nausea and vomiting were the only postoperative complications in our patient cohort (Table 2). No block-related complications, such as pneumothorax, local anesthetic intoxication, occurred.

## Discussion

This prospective randomized study showed that a single ESPB provided superior postoperative analgesia than the TPVB in patients undergoing video-assisted thoracoscopic lobectomy, which was different from recent studies. The other three studies all have proved that the analgesic effect of ESPB block is equal to or weaker than that of TPVB[14-16].

The most important reason was that high dose of local anesthetics were used in the ESPB block in our study. As with all interfascial plane blocks, ESP blocks are volume-dependent, and thus dermatomal coverage increases with increased volume[17, 18]. We had performed a preliminary experiment prior to this study which showed that ESPB with 0.3 mL/kg ropivacaine resulted in a narrow distribution of sensory loss (tested using pinprick sensation) at 30 min after administration. When the block was performed with a dose of 0.5 mL/kg ropivacaine, obvious loss of pinprick sensation over a wide area could be measured within 30 min. But in TPVB, we injected local anesthetics into the paravertebral region to block the anterior and posterior branches of spinal nerves, even sympathetic nerve fibers directly. Thus, the optimal analgesic effect of TPVB could be achieved after a single ropivacaine dose of 0.3 mL/kg, according to previous studies[19, 20] . The diffusion mechanism of local anesthetics in ESPB is different from that of TPVB, and it is appropriate for us to use different volumes of ropivacaine for the comparison of the two blocks.

Block failure or lack of efficiency of ESPB has also been reported by other literatures[21]. The focus of the dispute is whether ESPB can block the anterior branch of spinal nerve and sympathetic chain. And previous cadaveric studies radiological imaging reports differed on the spread of injectant of ESPB[17]. Some cadaveric and clinical evidences suggested that the local anesthetics could penetrate anteriorly through the intertransverse connective tissues into the paravertebral space where it blocked the ventral rami of the spinal nerves[7]. Additionally, the anesthetic might reach and block the rami communicantes and sympathetic chain to produce visceral analgesia[22-24]. The cadaver study by Adhikary and the magnetic resonance imaging study by Schwartzman concluded that the local anesthetics could spread to the the paravertebral space, neural foramina and epidural space [13, 25]. Vidal et al found that the injectant could also spread to the intercostal space, except for the paravertebral space[26]. However, Ivanusic et al. found that dye couldn't spread to the anterior of the paravertebral space to involve the origins of the ventral and dorsal branches of the thoracic spinal nerves[27]. The multilayered fascia deep to the erector spinae muscle may be the cause of different results from anatomic studies[17]. In our study, during the ESPB block we used a needle with a sharp tip in close contact with the transverse process to ensured that the tip of the needle broke through the multilayered fascia beneath the erector spinal muscle. That may be the second reason for the superior analgesia effect of ESPB in our study

Interestingly, the slower effect was observed despite the higher local anesthetic dose in the ESPB group than in the TPVB group. First, the dosage of intraoperative remifentanyl in ESPB group was not less than that in TPVB group. Second, postoperative pain control was superior in the ESPB group as compared to the TPVB group during 6–48 h after the operation, but not at 1 h. This implies that the effects of the ESPB were more persistent than those of the TPVB. This may occur because an anesthetic drug injected into the space between the transverse process and the erector spinae muscle may only gradually penetrate anteriorly through the intertransverse connective tissues and into the paravertebral space, epidural space or intercostal space [22, 23].

There were no block-related complications in our study, the only complications observed were nausea and vomiting. No case of local anesthetic intoxication and no case of pneumothorax occurred in both ESPB and TPVB groups. This suggests that the ESPB is safe for use in patients undergoing video-assisted thoracoscopic lobectomy. Additionally, the ESPB is less technically challenging than the TPVB. The erector spinae muscle and transverse process can be very easily imaged using a linear ultrasound transducer. Fang et al. has demonstrated that less block performing time, and higher success rate of puncture by once in ESPB group than in TPVB group[15].

There are several limitations to the current study. First, due to safety and time limitations, we only evaluated the block range 30 min after the block, but whether the block plane had been stabilized at this time needs further study. Second, we didn't measure the blood concentration of ropivacaine. There was no case of local anesthetic intoxication occurred in ESPB group in our study, after all, high volume and high concentration of ropivacaine increased the risk of local anesthesia toxicity[14, 17]. Thirdly, our study was

a randomized controlled trial with a small sample size from a single center. A multicenter study and more detailed experiments are needed to verify the effect and mechanism of ESPB.

## Conclusions

ESPB appeared to be a good alternative for postoperative pain management in patients undergoing video-assisted thoracoscopic lobectomy. Compared to TPVB, ESPB was associated with lower VAS pain scores, less analgesic consumption, and a greater analgesic effect.

## Abbreviations

TPVB: thoracic paravertebral block; ESP: erector spinae plane; BMI: Body mass index; ASA: American Society of Anesthesiologists; PCA: Patient-controlled analgesia; VAS: Visual analogue scale

## Declarations

### Ethics approval and consent to participate

The study was approved by the ethics committee of Beijing Chaoyang Hospital (2017-ke-81). The trial was registered retrospectively at the Clinical Trial Registry of China (ChiCTR-INR-17011499). Each patient provided a written informed consent.

### Consent for publication

Not applicable.

### Availability of data and materials

The main data have been presented in the article and its additional file (Additional file 1). All the other data and materials supporting the conclusions of this article are available from the corresponding author on reasonable request.

### Competing interests

The authors declare that they have no competing interests.

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### Authors' Contributions



DXM and HLR contributed equally to this work, in performing most of the experiments and writing the first draft manuscript. XYL, HLL, JJ and ASW performed or assisted with portions of the experiments and data analysis. YW designed and directed the project and wrote the final manuscript. All authors have read and approved the final manuscript.

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## Tables

**Table 1** General characteristics of the patients

Characteristic	Control group (n = 19)	TPVB group (n = 20)	ESPB group (n = 21)	P values
Age (y)	53.4 (8.5)	52.9 (7.6)	54.1 (9.4)	0.898
Sex				
Female	10 (53%)	12 (60%)	9 (43%)	0.897
Male	9 (47%)	8 (40%)	12 (57%)	0.897
Body mass index (kg/m <sup>2</sup> )	24.5 (4.7)	26.8 (6.5)	23.6 (5.8)	0.113
ASA status				
I	7 (37%)	8 (40%)	11 (52%)	0.572
II	12 (63%)	12 (60%)	10 (48%)	0.572
Duration of surgery (min)	179.3 (27.6)	190.5 (30.7)	187.2 (32.6)	0.701

Values are presented as mean± SD or number of patients (%)

*Abbreviations:* TPVB thoracic paravertebral block, ESPB erector spinae plane block, ASA American society of anesthesiologists, NS Not significant

**Table 2** Postoperative complications

Adverse effect	Control group (n = 19)	TPVB group (n = 20)	ESPB group (n = 21)	P value
Local anesthetic intoxication	0(0%)	0(0%)	0(0%)	0.99
Pneumothorax	0(0%)	0(0%)	0(0%)	0.99
Nausea	13(68.4%)	12(60%)	14(66.7%)	0.842
Vomiting	4(21.1%)	3(15%)	3(14.3%)	0.823

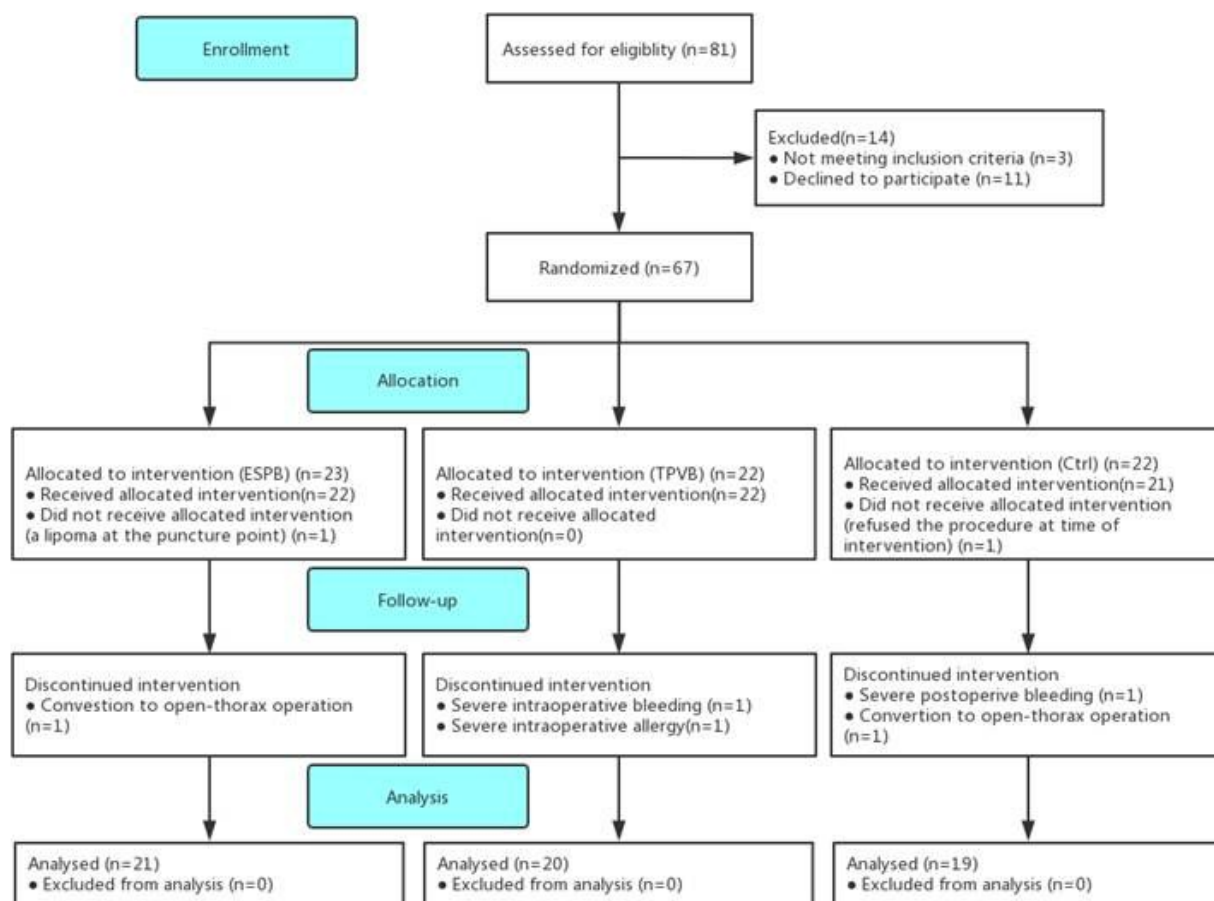
Data are given as number of patients (%).

*Abbreviations:* TPVB thoracic paravertebral block, ESPB erector spinae plane block

## Additional File Legend

Additional file 1: Original data. This is the dataset supporting the conclusions of this article, including demographic characteristics, VAS scores and dosage of analgesics (XLSX 21.5 kb)

## Figures



**Figure 1**

Flowchart of subject enrollment, allocation, randomization, follow-up and analysis.

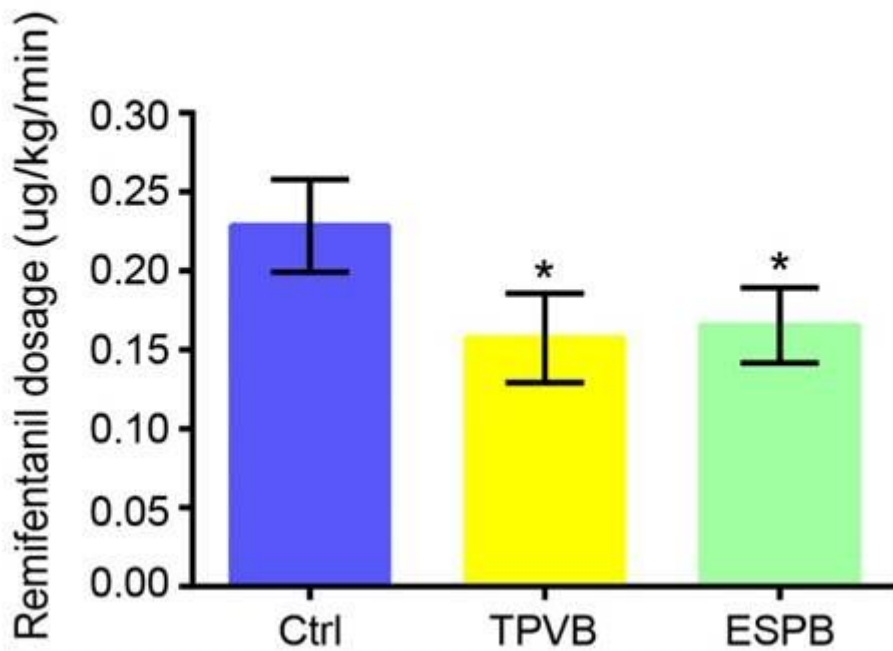


Figure 2

The dosage of remifentanyl used in the operation. \*P < 0.05 compared with the control group.

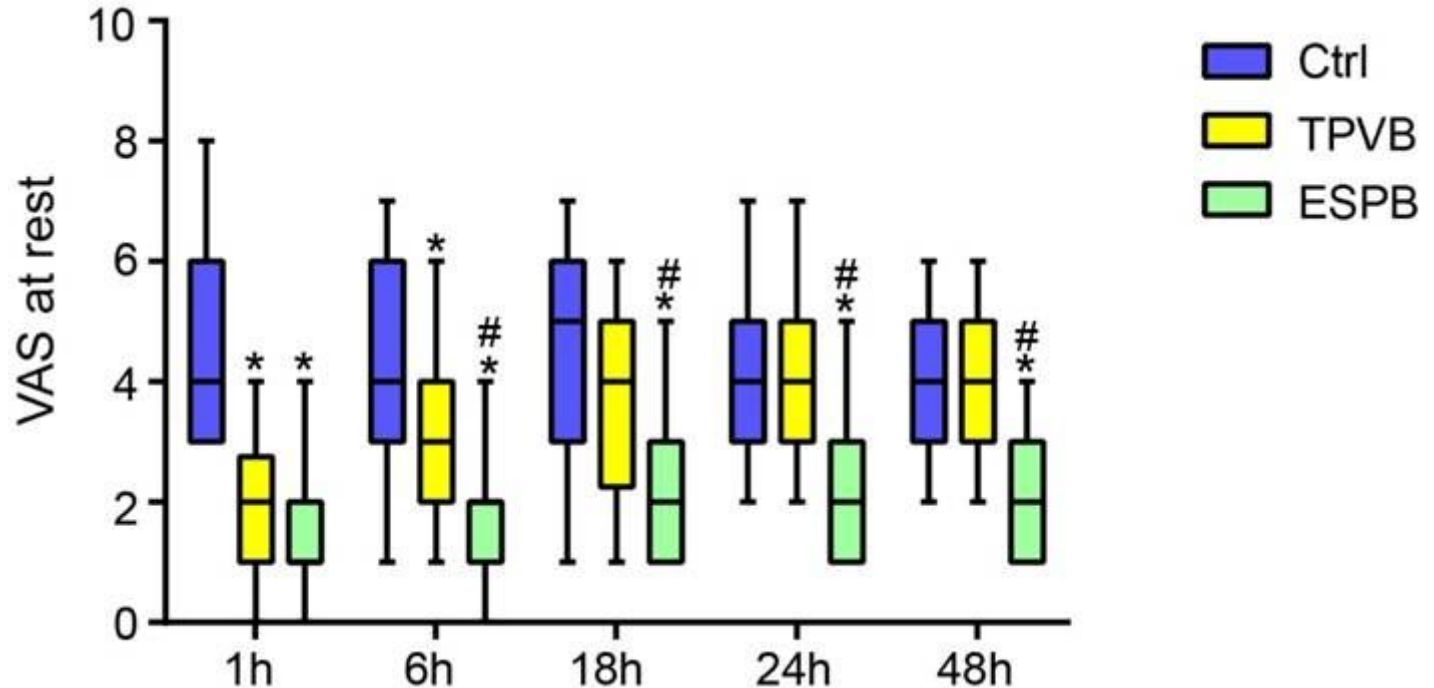


Figure 3

VAS at rest at 1, 6, 18, 24 and 48 hours after operation. The boxes represent interquartile range. The whiskers represent the lower and upper adjacent values. The horizontal line within the boxes represents

median. \*P < 0.05 compared with the control group; #P < 0.05 compared with the TPVB group.

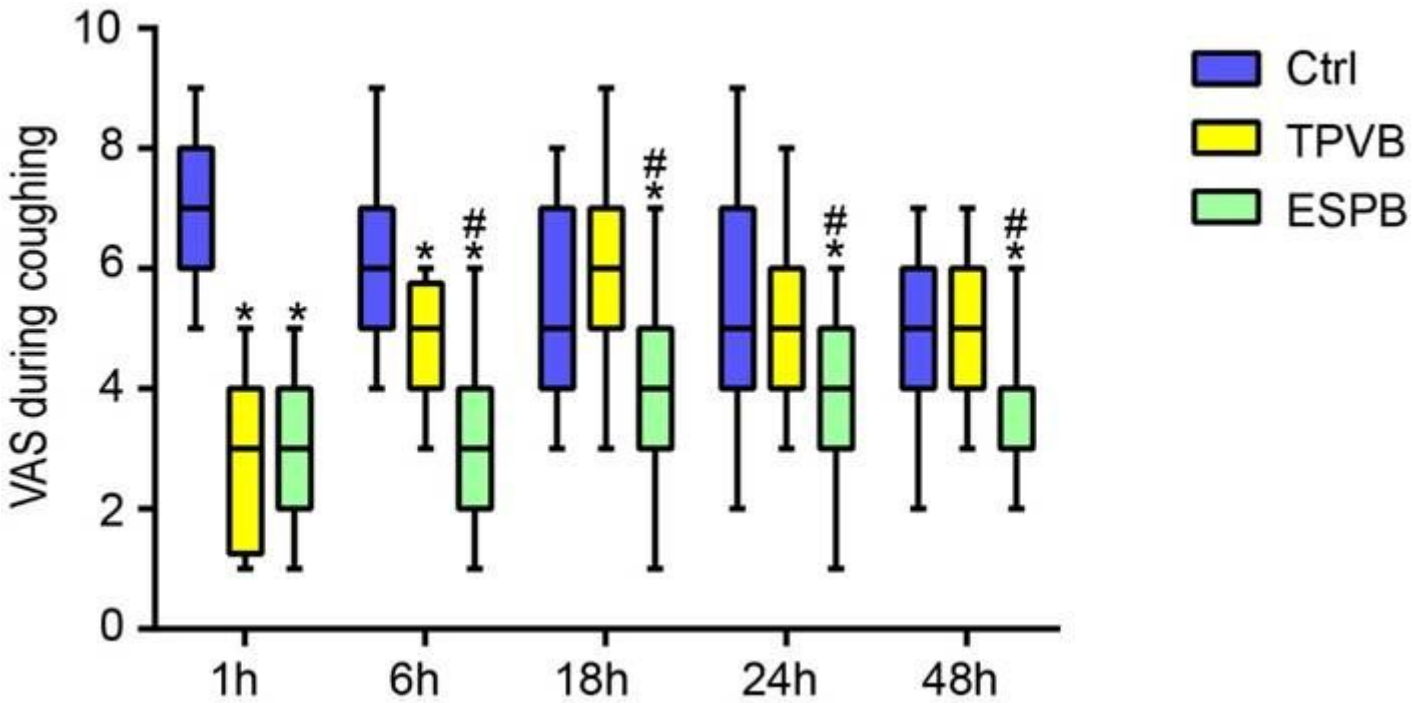


Figure 4

VAS at coughing at 1, 6, 18, 24 and 48 hours after operation. The boxes represent interquartile range. The whiskers represent the lower and upper adjacent values. The horizontal line within the boxes represents median. \*P < 0.05 compared with the control group; #P < 0.05 compared with the TPVB group.

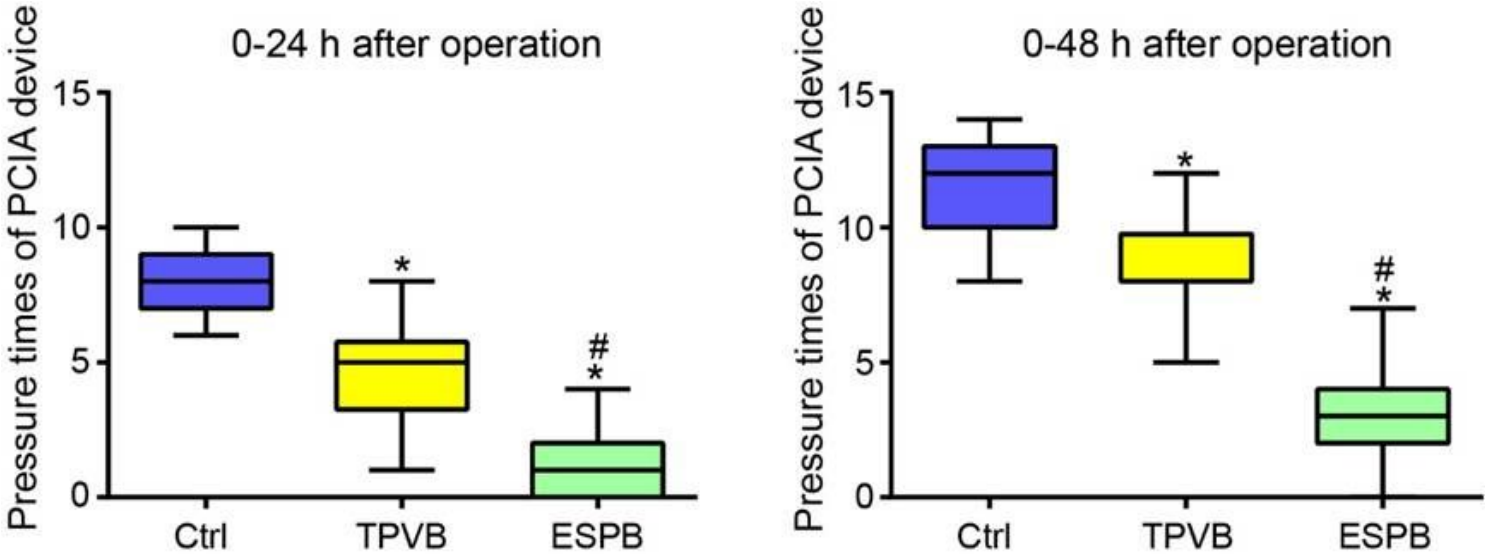
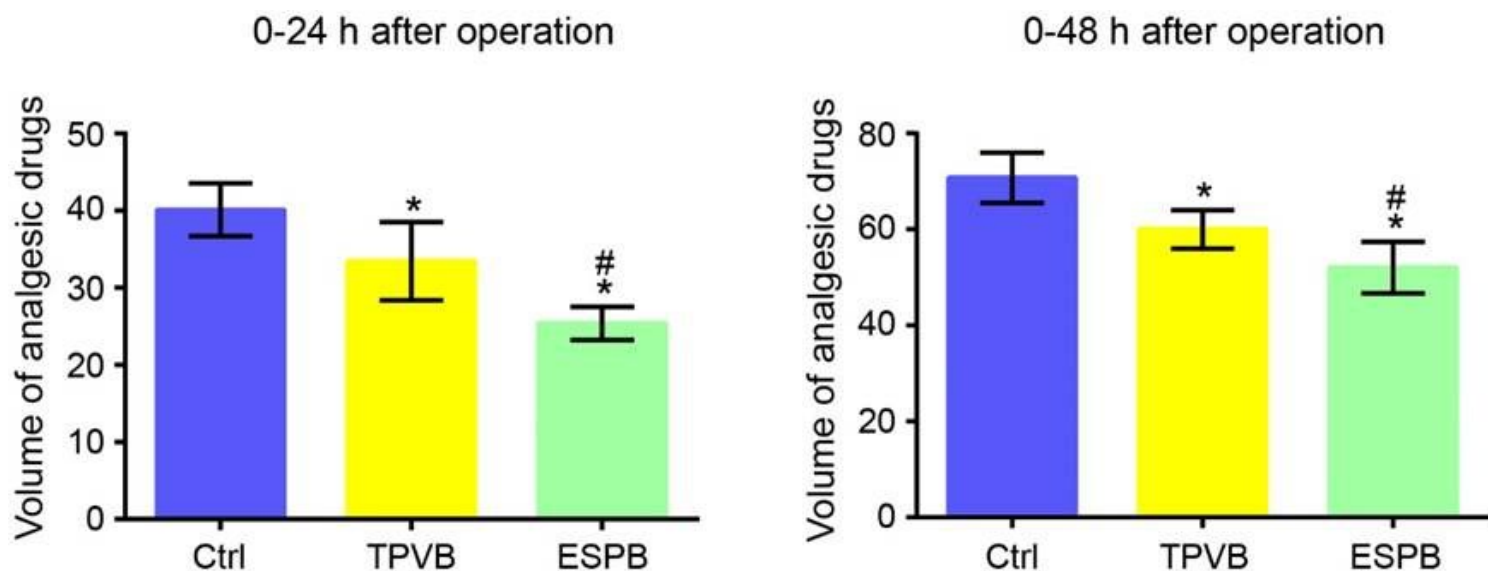


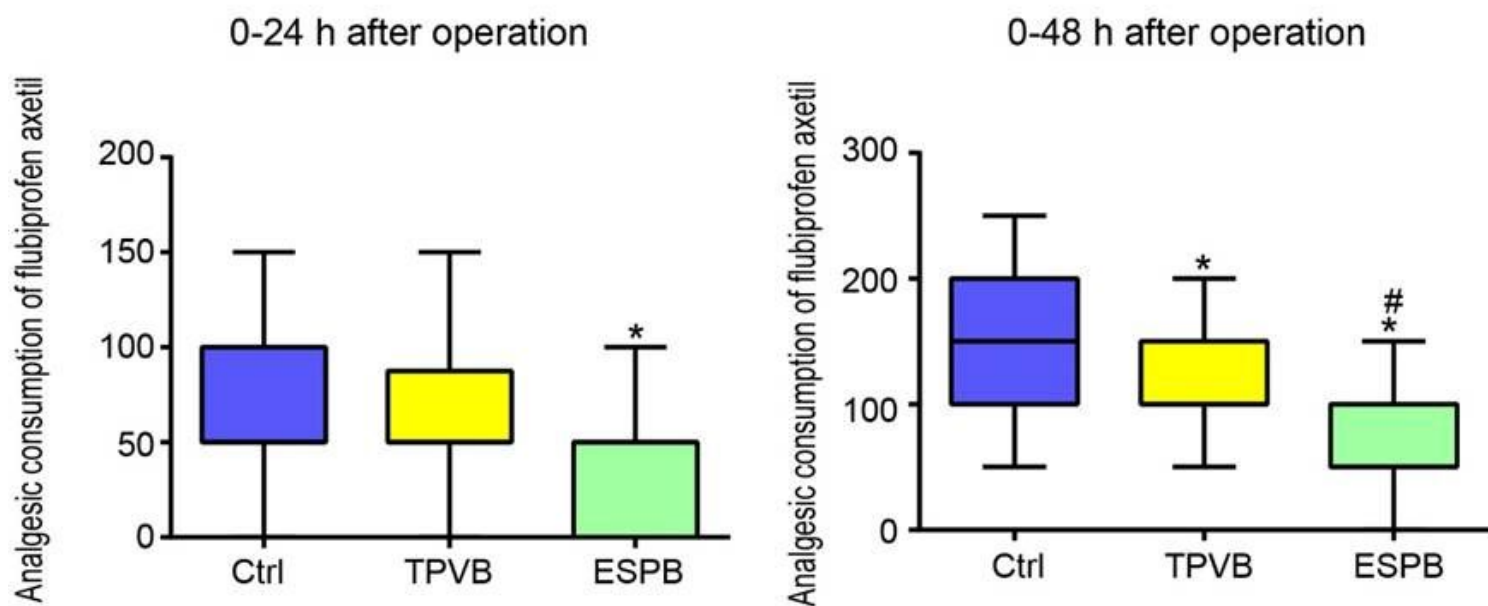
Figure 5

The number of PCIA doses delivered. The boxes represent interquartile range. The whiskers represent the lower and upper adjacent values. The horizontal line within the boxes represents median. \*P < 0.05 compared with the control group; #P < 0.05 compared with the TPVB group.



**Figure 6**

The volume of analgesic drugs administered via the PCIA device. \* $P < 0.05$  compared with the control group; # $P < 0.05$  compared with the TPVB group.



**Figure 7**

The consumption of flurbiprofen axetil. The boxes represent interquartile range. The whiskers represent the lower and upper adjacent values. The horizontal line within the boxes represents median. \* $P < 0.05$  compared with the control group; # $P < 0.05$  compared with the TPVB group.

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Additionalfile1.xlsx](#)