Brazilian Journal of Anesthesiology 2022;**72(1)**:115–121

Sociedade Brasileira de Anestesiologia

Brazilian Journal of ANESTHESIOLOGY

ORIGINAL INVESTIGATION

Effects of erector spinae plane block and retrolaminar block on analgesia for multiple rib fractures: a randomized, double-blinded clinical trial

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Received 9 September 2019; accepted 2 April 2021
Available online 22 April 2021

KEYWORDS
Clinical trial;
Rib fractures;
Nerve block;
Ultrasound imaging;
Analgesia

Abstract
Objective: To investigate the effects of Erector Spinae Plane Block (ESPB) and Retrolaminar Block (RLB) on intra- and postoperative analgesia in patients with Multiple Rib Fractures (MRFs).
Methods: A total of 80 MRFs patients were randomly divided into the ESPB (Group E) and RLB (Group R) groups. After general anesthesia, ESPB and RLB were performed under ultrasound guidance, respectively, together with 20 mL of 0.5% ropivacaine and Patient-Controlled Intravenous Analgesia (PCIA).
Results: Thirty-four cases in Group E and 33,cases in Group R showed unclear paravertebral spaces. The intraoperative dosage of remifentanil (mean ± SD) (392.8 ± 118.7 vs. 501.7 ± 190.0 μg) and postoperative morphine PCIA dosage, (7.35 ± 1.55 vs. 14.73 ± 2.18 mg) in Group R were significantly less than those in Group E; the Visual Analog Scale (VAS) scores in Group R at 2 (2.7 ± 1.2 vs. 3.4 ± 1.4), 4 (2.2 ± 1.1 vs. 2.8 ± 0.9), 12 (2.5 ± 0.9 vs. 3.0 ± 0.8), and 24 hours (2.6 ± 1.0 vs. 3.1 ± 0.9) after surgery were significantly lower than those in Group E. Finally, the normal respiratory diaphragm activity (2.17 ± 0.22 vs. 2.05 ± 0.19), pH (median [IQR] (7.38 [7.31–7.45] vs. 7.36 [7.30–7.42]), and partial pressure of carbon dioxide ($PaCO_2$) (44 [35–49] vs. 42.5 [30–46]) after the operation in Group R were significantly better than those in Group E (p < 0.05).
Conclusions: RLB was a more effective analgesic method than ESPB in the treatment of MRF.

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https://doi.org/10.1016/j.bjane.2021.04.004

Introduction

Rib fractures are the most common injury among blunt thoracic trauma, accounting for 55% of cases.[1] Severe pain, hemopneumothorax, pulmonary contusion, and hypoxemia often accompany operations for Multiple Rib Fractures (MRFs). Severe postoperative pain can cause atelectasis, pneumonia, or respiratory failure, which affect the recovery of respiratory function.[2] Good postoperative analgesia plays a very important role in patient recovery. Thoracic paravertebral nerve block acts on the unilateral somatic and sympathetic nerves to provide effective postoperative analgesia for thoracic, breast, kidney, and other operations and is a commonly used analgesic method in thoracic surgery.[3] However, due to the frequent combination of pneumothorax, pleural effusion, and even hemopneumothorax in patients with MRFs, it is not easy to identify the paravertebral space and the ventral transposition of the pleura cannot be observed in some patients during administration of the local anesthetic or saline, which increases the incidence of failure of parathoracic nerve block and pleural puncture. In recent years, Erector Spinae Plane Block (ESPB) and Retrolaminar Block (RLB) are common alternatives to thoracic paravertebral nerve block.[4,5] ESPB is defined as the injection of local anesthetics between the erector spine muscle and the transverse process while RLB is defined as the injection of local anesthetics between the lamina and transversospinalis muscle.[6] The local operation of these blocks is relatively simple and superficial and they can provide good analgesia during the perioperative period of thoracic surgery.[7–9] The present study investigated the effects of ultrasound-guided ESPB and RLB on intraoperative and postoperative analgesia in patients with MRFs to identify a safe and effective regional block method for clinical anesthesia.

Methods

Subjects

This study was conducted in accordance with the principles of the Declaration of Helsinki and was conducted with approval from the Ethics Committee of Beijing Jishuitan Hospital (IRB201909-32) and registered in the Chinese Clinical Trials Registry (Registration Nº: ChiCTR1900022185). Written informed consent was obtained from all participants. This study included a total of 80 patients with American Society of Anesthesiologists (ASA) physical Status I–III aged 18–65 years who had been diagnosed with MRFs in the right chest and scheduled to undergo internal fixation. The exclusion criteria were bilateral chest trauma; rib fracture < 3 or > 6 sites; local anesthetic drug allergy; local infection at the puncture site; cardiac insufficiency; renal insufficiency; nervous system abnormality; or coagulation dysfunction. The patients were randomly divided into the ESPB (E) and RLB (R) groups by a computer-generated random numbers table. The grouping numbers were stored in a closed envelope that was opened only after the induction of general anesthesia on the day of surgery. This study was a double-blind trial in which all patients underwent ESPB or RLB after general anesthesia, so no patient was aware of the analgesic method. The same anesthesiologist was responsible for ESPB or RLB, while different anesthesiologists were responsible for anesthesia implementation and postoperative follow-up.

Treatments

Electrocardiogram (ECG), invasive arterial blood pressure, and oxygen saturation (SpO_2) were monitored routinely after each patient was sent to the operation room. General anesthesia induction used intravenous fentanyl (3 $\mu g.kg^{-1}$) and propofol (1–2 $mg.kg^{-1}$); when the patient was unconsciousness, rocuronium (0.1 $mg.kg^{-1}$) was administrated and anesthesia was maintained with sevoflurane (maintained at 0.8–1 Minimum Alveolar Concentration [MAC]), remifentanil, and rocuronium. ESPB and RLB were performed in both groups after general anesthesia. After general anesthesia, each patient was placed in the lateral decubitus position and the rib fracture segment was located by ultrasound and punctured in the middle of the fracture segment. ESPB and RLB were performed after sterile disinfection. The same ultrasound device (Wisonic C., Ltd, Shenzhen, CN) was used for both groups.

ESPB[10]

Group E: The sagittal position of the ultrasound probe was placed on the lateral side of the posterior median line to locate the transverse process and erector spine muscle of the target segment (Fig. 1A). The puncture was performed using the intra-plane needling technique. The puncture needle (PAJUNK, SonoPlex stim cannula, Geisingen, Germany; 80 mm) was punctured from head to tail. When the puncture needle touched the transverse process, with no blood, gas, or cerebrospinal fluid observed when the needle was drawn back, 20 mL of 0.5% ropivacaine (AstraZeneca AB, Sweden) was administered between the erector spine muscle and transverse process. Local anesthetic diffusion between the transverse process and erector spine muscle indicated a successful puncture.

RLB[5]

Group R: The sagittal position of the ultrasound probe was placed on the lateral side of the posterior median line to locate the lamina, erector spine muscle, and transversospinalis muscles of the target segment (Fig. 1B). The puncture was performed using the intra-plane needling technique. The puncture needle was punctured from head to tail. When the puncture needle touched the lamina, with no blood, gas, or cerebrospinal fluid observed when the needle was drawn back, 20 mL of 0.5% ropivacaine was administered between the transversospinalis muscle and lamina. Local anesthetic diffusion between the lamina and the erector spine muscle indicated a successful puncture.

The transverse section and paramedian sagittal paravertebral space were observed by ultrasound in both groups. All patients were anesthetized by the same anesthesiologist and operated on by the same group of surgeons. PCIA was administered to both groups after the operation. The prescription was morphine (1 $mg.mL^{-1}$) without background

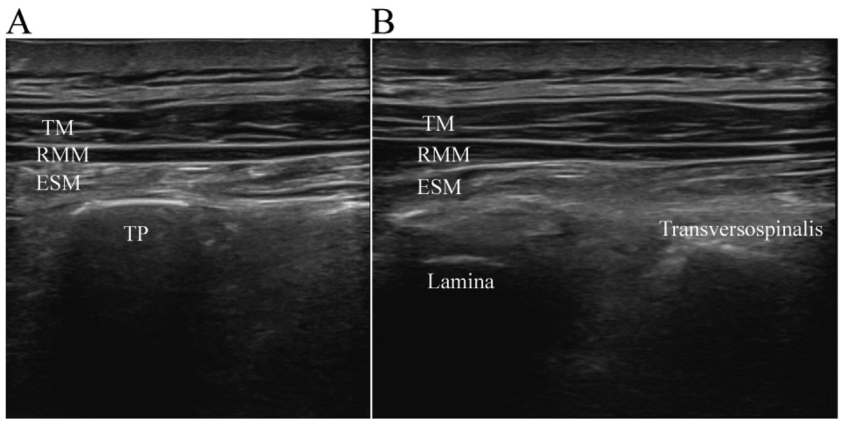

Figure 1 Ultrasound images of erector spinae plane block and retrolaminar block: (A) Erector spinae plane block; (B) Retrolaminar block. Trapezius Muscle (TM), Rhomboid Major Muscle (RMM), Erector Spinae Muscle (ESM), Transverse Process (TP), Pleural Effusion (PE), Transversospinalis Muscle (Transversospinalis).

measurement, 1 mg of morphine with self-control measurement, with a locking time of 15 minutes.

Measurements

The main measurements were intraoperative remifentanil and morphine dosage and pain assessment. The secondary measurements included normal respiratory diaphragm activity, blood gas analysis, and adverse reactions before and after surgery. Patient pain was assessed before the operation and at 2, 4, 12, 24, and 48 hours after surgery by a resident not involved in the study. VAS score was used to assess pain (VAS score: 0−10 points; 0 points: no pain, 10 points: severe pain).[11] Complications and adverse reactions related to the puncture were recorded, including pleural perforation, hematoma, intraspinal diffusion, nausea, or vomiting. Ultrasound was used to assess diaphragm activity during normal breathing with a 2−5 MHz low-frequency probe. During the assessments, each patient was placed in a supine position with the probe placed between the axillary and clavicular midlines at the lower edge of the costal arch. The diaphragm was scanned in B-MODE and respiratory movement was evaluated in M-MODE.[12] Postoperative nausea and vomiting were assessed in four grades: Grade 0, no nausea and vomiting; Grade 1, mild nausea; Grade 2, severe nausea or vomiting once; and Grade 3, vomiting more than once. If the score was more than 2 points, ondansetron (0.1 $mg.kg^{-1}$) was administered.

Statistical analysis

Clinical data were collected and analyzed using IBM SPSS Statistics for Windows, version 21.0. Statistical data were tested for normal distribution by Kolmogorov-Smirnov tests and measurement data with normal distributions expressed as mean ± Standard Deviation (SD), while those with non-normal distribution were expressed as medians. Continuous data were compared by two independent-sample *t*- and Mann-Whitney *U* tests, while intergroup count data were compared using x^2 tests, with $p < 0.05$ indicating statistical significance.

Table 1 Comparison of general situation between two groups (mean ± SD).

	E	R	*p*
Age	41(26,62)	44(23,63)	> 0.05
Gender (M/F)	26/14	30/10	> 0.05
Height	165.7 ± 6.3	163 ± 7.7	> 0.05
Weight	68.8 ± 11.3	65.3 ± 9.9	> 0.05
ASA physical status (I/II)	34/6	30/10	> 0.05
Operation time	119.3 ± 20.0	111.6 ± 22.3	> 0.05

This study was mainly an analgesic study. The preliminary experiments in this study showed that the intraoperative remifentanil dosage in Group R was less than that in Group E (390.0 ± 118.8 vs. 481.8 ± 159.5 μg) at a significance level of 0.05 and a power of 80%. We estimated that the minimum sample size was 37 patients per group; thus, this study included 40 patients per group.

Results

A total of 136 patients were initially included in this study but 56 were excluded for return to the Intensive Care Unit (ICU) (n = 6), combined with multiple trauma (femoral fracture, humeral shaft fracture, facial fracture, etc.; n = 43), and refusing to participate (n = 7). The CONSORT flow diagram is shown in Figure 2.

Comparisons of the general situations between groups

All patients in this study were treated with direct locking reconstruction plates for MRFs. There were no significant differences in age, sex, weight, height, ASA physical status, and operation time between the two groups ($p > 0.05$) (Table 1).

Unclear paravertebral spaces were observed in 34 cases (85%) in Group E and 31 cases (78%) in Group R (Fig. 3). ESPB or RLB were successfully performed in both groups, respec-

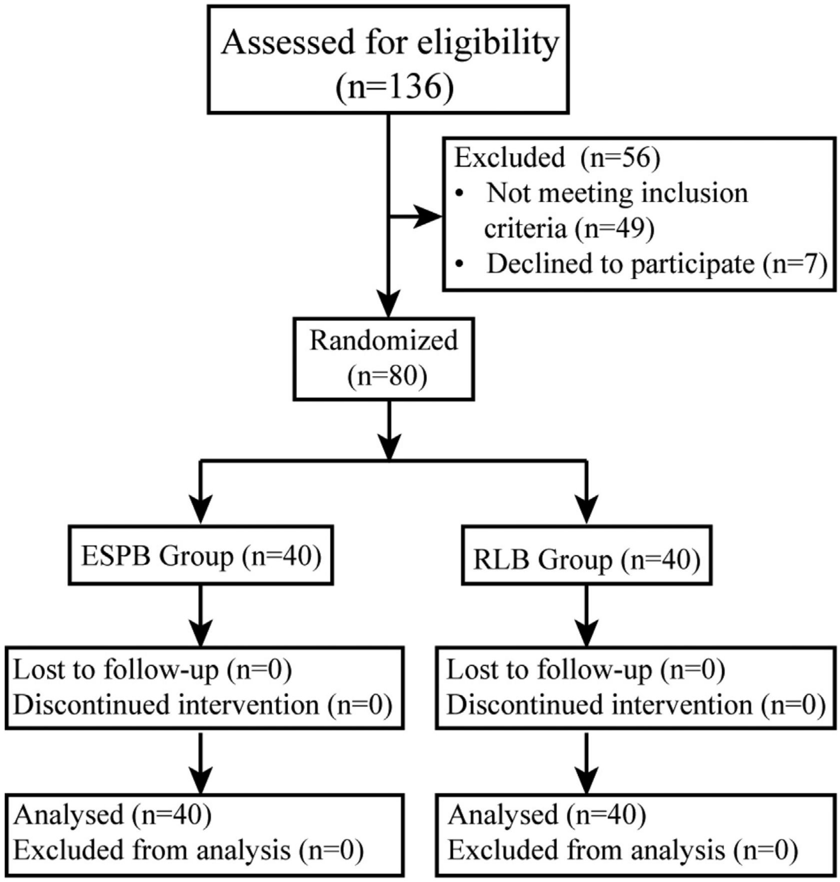

Figure 2 CONSORT Flow diagram.

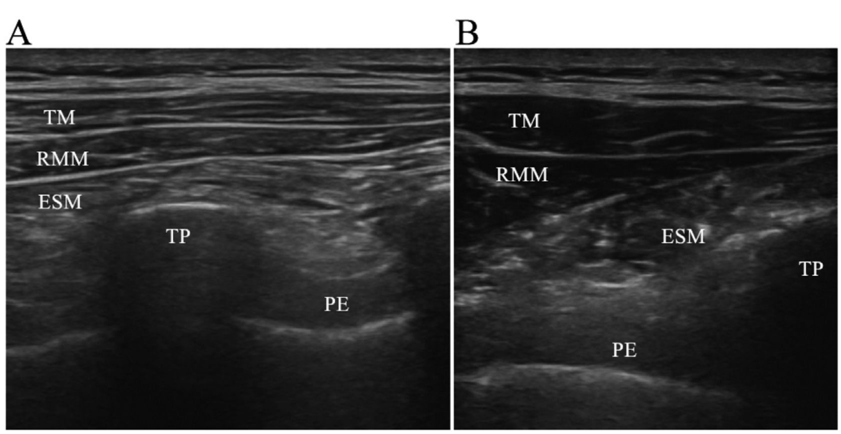

Figure 3 Scanning of paravertebral space in MRF patients: (A) sagittal scanning of paravertebral space. (B) Transverse scanning of paravertebral space. Trapezius Muscle (TM), Rhomboid Major Muscle (RMM), Erector Spinae Muscle (ESM), Transverse Process (TP), Pleural Effusion (PE).

tively. No local anesthetic toxicity, neurovascular injury, pleural perforation, or hematoma occurred in either group.

Comparisons of intra- and postoperative analgesia between groups

The dosages of remifentanil during operation (mean ± SD) (392.8 ± 118.7 vs. 501.7 ± 190.0 μg) and morphine after the operation (7.35 ± 1.42 vs. 14.73 ± 2.18 mg) in Group R were significantly lower than those in Group E ($p < 0.05$) (Table 2). There were no significant differences in diaphragm activity and blood gas analysis between the two groups before surgery ($p > 0.05$) (Table 3). The VAS score in Group R was significantly lower than that in Group E at 2 (mean ± SD) (2.7 ± 1.2 vs. 3.4 ± 1.4), 4 (2.2 ± 1.1 vs. 2.8 ± 0.9), 12 (2.5 ± 0.9 vs. 3.0 ± 0.8, and 24 hours (2.6 ± 1.0 vs. 3.1

Table 2 Comparison of intraoperative remifentanil and postoperative morphine dosage between two groups (mean ± SD).

	E	R	*p*
Intraoperative dosage of remifentanil (μg)	501.7 ± 190.0	392.8 ± 118.7	< 0.01
Morphine dosage after operation (mg)	14.73 ± 2.18	7.35 ± 1.55	< 0.001

Table 3 Comparison of diaphragm activity and blood gas analysis between groups (mean ± SD).

	E	R	*p*
PH, median (IQR)			
Before surgery	7.45 (7.37–7.49)	7.45 (7.38–7.49)	0.54
After surgery	7.36 (7.30–7.42)	7.38 (7.31–7.45)	0.04
PaO_2, mmHg			
Before surgery	68.5 ± 13.7	67.6 ± 14.3	0.78
After surgery median (IQR)	59.5 (41–99)	56.5 (40–96)	0.91
$PaCO_2$, mmHg			
Before surgery	34.8 ± 2.9	35.9 ± 4.3	0.18
After surgery median (IQR)	44 (35–49)	42.5 (30–46)	0.04
Diaphragm activity, mm			
Before surgery	1.52 ± 0.18	1.44 ± 0.24	0.12
After surgery	2.05 ± 0.19	2.17 ± 0.22	0.007

IQR, Interquartile Range.

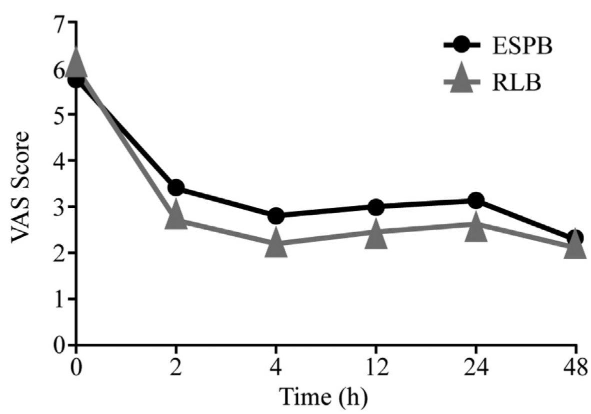

Figure 4 Comparison of VAS scores between groups.

± 0.9) after the operation ($p < 0.05$). We observed no significant differences in VAS scores between the two groups before and 48 hours after the operation ($p > 0.05$) (Fig. 4). Six patients (15%) in Group R and 11 patients (28%) in Group E had postoperative nausea and vomiting, with the incidence of nausea and vomiting in Group R significantly lower than that in Group E.

Comparisons of diaphragmatic activity and blood gas analysis between groups

The normal breathing diaphragm activity (mean ± SD) (2.17 ± 0.22 vs. 2.05 ± 0.19 mm), PH value (median [IQR]) (7.38 [7.31–7.45] vs. 7.36 [7.30–7.42]), and $PaCO_2$ (median [IQR], 44 (35–49) vs. 42.5 (30–46)] after the operation in Group R were significantly better than those in Group E ($p < 0.05$) (Table 3).

Discussion

Early surgical treatment is the first choice for patients with MRFs and has a good prognosis.[13] However, patients with MRFs have severe pain after surgery, which hinders their recovery and increases the incidence of pulmonary complications after surgery.[14] Moreover, the use of muscle relaxants and opioids during the perioperative period damages further respiratory function. Effective perioperative analgesia is the basis of perioperative management for patients with MRFs, for which regional block techniques can be effective.[15]

Thoracic epidural anesthesia is the golden standard of analgesia in thoracic surgery, with paravertebral nerve block also a widely used analgesic method in thoracic surgery. Previous studies have proved that these two methods can be used for analgesia in MRFs.[16,17] However, the results of the present study showed that these two methods are not suitable for patients with MRFs for the following reasons:: 1) Previous studies have demonstrated that patients with MRFs have severe pain before surgery, even when they move slightly.[18] In the present study, the patients in the two groups had high VAS scores before surgery and could not cooperate with the implementation of thoracic epidural anesthesia and TPVB before general anesthesia; 2) Patients with MRFs often also have pleural effusion. In this study, the ultrasound images of 65 patients did not clearly show the parathoracic space, which made puncture difficult and increased the risks of the puncture needle breaking the pleura or administration in the incorrect location in these patients. One reason for the lack of clear view of the paravertebral space may be that the pleural effusion was located below the wall cavity of the affected side, between the visceral pleura and the parietal pleura. Compression of the parietal pleura by the pleural effusion resulted in the narrowing of paravertebral space, leading to the unclear ultrasound images.

RLB and ESPB are thoracic interfacial block methods that are simple to perform. Local anesthetics can diffuse longitudinally along the ventral surface of the erector spinae and block the dorsal ramus of the spinal nerve, block the ventral ramus of the spinal nerve through the costal transverse foramen, and even enter the paravertebral space.[10,19] In autopsy studies, ESPB and RLB blocked the ventral rami of the spinal nerve, while clinical studies also showed that ESP and RLB can provide effective analgesic effects for thoracic surgery.[20–22] In this study, ESPB and RLB were performed with 20 mL of 0.5% ropivacaine for regional block anesthesia to provide good analgesic effect during and after the operation and promote early patient recovery. The results of the present study showed significantly reduced dosages of remifentanil during the operation and morphine after the operation in Group R, with a low incidence of postoperative nausea and vomiting. The pain scores between 2 and 24 hours after the operation in Group R were significantly lower than those in Group E, indicating that the analgesic effect of RLB is significantly better than that of ESPB; however, the analgesic effect of RLB was similar to that of ESPB at 48 hours. The difference in analgesic effect between the two methods may be due to the injection of local anesthetics into different fascial layers. In RLB, the local anesthetics were injected between the transverse process and lamina, deeper than the transversospinalis muscles. In ESPB, the injections were administered between the erector spinae muscle and the transverse process, which caused differences in drug diffusion and led to different analgesic effects.

Previous clinical studies used diaphragm activity and blood gas analysis to assess patient respiratory function.[23–25] Severe preoperative pain in patients with MRFs may affect the results of pulmonary function tests. Therefore, the present study used these two methods to evaluate the recovery of patient postoperative pulmonary function. Because RLB can provide good intraoperative and postoperative analgesia, the patients' postoperative pain score was low and the diaphragm activity in Group R was better than that in group E, suggesting better recovery of pulmonary ventilation function in Group R. At the same time, this study improved the pulmonary ventilation function by surgical treatment and good postoperative analgesia of RLB. The $PaCO_2$ and pH values in group R were better than those in Group E. However, patients with MRFs are commonly complicated with pulmonary contusion, which may affect the pulmonary diffusion function of patients and cannot be by improved by non-surgical treatment; thus, PaO_2 did not differ significantly between the two groups in this study.

This study has some limitations: 1) The subjects of this study were patients with MRFs, who often experience such severe pain before surgery that it is difficult to perform with the patients awake. All the patients in this study received regional block under general anesthesia and there was no way to observe the onset time of these two nerve block methods and the blocked sensory segment; thus, it was impossible to judge whether the two methods would cause a bilateral block; 2) In this study, blood gas analysis and diaphragm activity to observe and analyze patient breathing and lung functions could not be performed due to preoperative pain. In future studies, we will study ESPB and RLB in patients undergoing different thoracic surgery to further explore the differences between these two regional block methods.

At present, various regional analgesic methods can be applied to patients with MRFs. In these patients, RLB may provide a better analgesic effect than that of ESPB for the same volume of local anesthetics, significantly reduce the intra- and postoperative use of opioids, and promote the recovery of pulmonary function after surgery. Therefore, RLB is a safer and more effective regional block method for patients with MRFs. However, this study has some additional limitations. Patients with MRFs had abnormal chest wall sensation and we did not compare the sensory block segments of these two regional blockades. In addition, ESPB is an interfacial block. In this study, only 20 mL of local anesthetics was administered; additional research is needed to investigate whether increasing the volume of local anesthetics can provide better analgesic effects.

Conflicts of interest

The authors declare no conflicts of interest.

Funding

This study was supported by Beijing JST Research Funding (code: QN-201915).

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