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Analgesic effects of different approaches for two-point thoracic paravertebral block

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Abstract: Objective To compare the postoperative analgesic efficacy of the in-plane versus out-of-plane approach for ultrasound-guided thoracic paravertebral block (TPVB) in patients undergoing thoracoscopic lobectomy. **Methods** A total of 102 patients scheduled for elective thoracoscopic lobectomy at Qilu Second Hospital of Shandong University from January to August 2025 were enrolled and randomly divided into an in-plane group (IP group, n=51) and an out-of-plane group (OOP group, n=51). All patients received a single-shot ultrasound-guided TPVB in the anesthesia preparation room before surgery. the primary outcome measure was the Visual Analogue Scale (VAS) score at 6 hours postoperatively. Secondary outcomes included cough VAS scores at 1, 2, 12, and 24 hours postoperatively, area under the curve (AUC) of VAS 24 hours postoperatively block performance time, needling depth, block onset and fixation time, extent of sensory block, intraoperative opioid consumption, patient satisfaction, and adverse reactions. Multivariate linear regression was used to analyze factors influencing the VAS-AUC at 24 hours postoperatively. **Results** There was no statistically significant difference between the two groups in VAS scores at various postoperative time points, 24-hour VAS-AUC, intraoperative opioid consumption, patient satisfaction, or incidence of intraoperative adverse reactions (P> 0.05). Compared with the IP group, the OOP group had a significantly shorter block performance time [194.00 (181.00, 217.00) s *vs* 227.00 (201.00, 259.50) s, Z=4.803, P<0.01]and shallower needling depth [2.80 (2.30, 3.40) cm *vs* 3.50 (3.00, 4.00) m, Z=4.854, P<0.01]. Multivariate linear regression analysis showed that sensory block extent, block onset time, and age were independent influencing factors of postoperative pain (P<0.05). **Conclusion** For thoracoscopic lobectomy, the out-of-plane approach for ultrasound-guided TPVB provides comparable postoperative analgesia to the in-plane approach, while offering the advantages of being more convenient to perform and requiring a shallower needling depth. the extent of sensory block, onset time block, and patient age are key factors influencing the analgesic efficacy of the out-of-plane TPVB approach.

Keywords: Ultrasound-guided; Video-assisted thoracoscopic surgery; Thoracic paravertebral block; Postoperative analgesia; In-plane approach; Out-of-plane approach

Video-assisted thoracoscopic surgery (VATS) is the primary minimally invasive treatment for lung cancer. However, patients still often experience severe and persistent pain after surgery, which not only hinders the recovery of respiratory function but also increases the risk of complications such as pulmonary infection and atelectasis [1]. Thoracic paravertebral block (TPVB) is one of the preferred regional anesthesia techniques for multimodal analgesia after thoracic surgery [2]. By blocking the transmission of pain signals in the surgical area, it can effectively relieve pain, reduce opioid consumption, and lower the incidence of postoperative nausea and vomiting (PONV), delirium, and pulmonary complications [3-4]. the application of ultrasound guidance technology makes the paravertebral space more clearly visible, significantly improving the accuracy and safety of TPVB puncture [5]. Currently, ultrasound-guided TPVB is mainly divided into in-plane and out-of-plane approaches based on the relationship between the needle trajectory and the ultrasound beam plane, but there is still controversy regarding the clinical analgesic effects and blocking efficacy of the two approaches [6-7]. This study aims to compare the analgesic effects and operation-related indicators of ultrasound-guided in-plane versus out-of-plane TPVB for postoperative analgesia after VATS, and to analyze the influencing factors of postoperative pain scores through linear regression analysis, so as to provide clinical evidence for optimizing TPVB approach selection and analgesic regimens for patients undergoing thoracic surgery.

1 Data and Methods

1.1 General Data

This study is a prospective study. Patients scheduled for elective uniportal thoracoscopic lobectomy at the Second Affiliated Hospital of Shandong University Qilu from January 2025 to August 2025 were selected.

Inclusion criteria:

(1) age 18-80 years;

(2) body mass index (BMI) 18.5-28.0 kg/m²;

(3) American Society of Anesthesiologists (ASA) physical status classification I to III;

(4) scheduled for elective uniportal thoracoscopic lobectomy.

Exclusion criteria:

(1) refusal to participate in the study or inability to sign informed consent;

(2) uncontrolled severe mental or neurological diseases, or long-term use of related medications;

(3) cognitive dysfunction or severe sensory/language disorders making communication and assessment impossible;

(4) moderate to severe chronic pain [Visual Analogue Scale (VAS) ≥ 4] within 3 months before surgery or regular use of analgesics;

(5) history of drug (especially opioids) or alcohol abuse;

(6) active infection at the puncture site or systemic active infection;

(7) significant coagulation abnormalities;

(8) severe uncontrolled systemic diseases (e.g., cardiac, hepatic, renal insufficiency);

(9) severe spinal deformity or history of ipsilateral thoracic surgery;

(10) allergy to local anesthetics such as ropivacaine;

(11) pregnant or lactating women;

(12) conversion to thoracotomy or occurrence of severe complications during surgery.

This study was approved by the Scientific Research Ethics Committee of the Second Qilu Hospital of Shandong University (Approval Number: KYLL2025016).

1.2 Sample Size Calculation and Grouping

Sample size was estimated using PASS 21 software. the primary endpoint was VAS at 6 hours postoperatively during coughing. Based on pilot study data and clinical significance, the non-inferiority margin (Δ value) was set at 1.0 point [8]. the VAS score in the OOP group was (4.0±1.0) points, and in the IP group was (4.4±0.9) points. A one-sided significance level α=0.025 and power of 80% were set. Calculation showed that at least 43 patients were needed per group. Considering a dropout rate of 20%, 54 patients were planned to be enrolled per group, for a total sample size of 108 subjects. the 108 patients were randomly assigned to the out-of-plane approach group (OOP group, n=54) or the in-plane approach group (IP group, n=54) using a random number table method. During the trial, a total of 6 patients dropped out: 1 converted to open surgery, 1 withdrew informed consent, and 4 were lost to follow-up. Ultimately, 51 patients in each of the OOP and IP groups completed the trial and were included in the final analysis.

1.3 Ultrasound-Guided TPVB

Patients entered the anesthesia preparation room 1 hour before surgery, an intravenous line was established, and local infiltration anesthesia was performed before radial artery puncture and catheterization. Subsequently, the patient was placed in the lateral decubitus position (surgical side up). After intravenous injection of midazolam 0.02 mg/kg (National Drug Approval Number H19990027, 1 mL:5 mg, Jiangsu Nhwa Pharmaceutical) for sedation, ultrasound-guided two-point TPVB was performed. Using a 2-5 MHz low-frequency convex array probe, the C_7 spinous process was first identified in the sagittal plane and scanned caudally. Two target blockade levels (T_4 and T_7) were determined according to the surgical area.

Puncture at each level was performed according to the grouping strategy described below:

In the IP group, the probe was rotated 90° and placed approximately 2.5 cm lateral to the spinous process to obtain a transverse plane image. the block needle was inserted from the lateral side within the ultrasound plane, and under full visualization, it penetrated the superior costotransverse ligament (SCTL) to enter the paravertebral space (PVS).

In the OOP group, the probe was kept in the sagittal plane and moved laterally until adjacent transverse processes, SCTL, and pleura were simultaneously displayed. the block needle was inserted perpendicular to the long axis of the probe, and the needle tip was tracked by fine-tuning the probe to make it penetrate the SCTL and enter the PVS.

After proper needle placement, negative aspiration was performed. After confirming no blood or cerebrospinal fluid return, 2-3 mL of 0.9% sodium chloride solution was injected. After ultrasound confirmed ventral displacement of the pleura and widening of the PVS, 15 mL of 0.33% ropivacaine was injected in fractions at each level, and the drug diffusion and pleural downward displacement were observed.

1.4 Anesthesia Method

After entering the operating room, all patients underwent continuous monitoring of oxygen saturation, electrocardiogram, heart rate, invasive blood pressure, body temperature, and entropy index. Anesthesia induction: intravenous injection of sufentanil (National Drug Approval Number H20054171, 1 mL:50 μg, Yichang Humanwell Pharmaceutical) 0.5 μg/kg, propofol (National Drug Approval Number HJ20150654, 20 mL:200 mg, Fresenius Kabi Austria) 1.5-2.5 mg/kg, and rocuronium bromide (National Drug Approval Number H20213778, 5 mL:50 mg, Guangdong Xinghao Pharmaceutical) 0.8 mg/kg.

After loss of consciousness and adequate muscle relaxation, endotracheal intubation and mechanical ventilation were performed. Tidal volume was set to 8-10 mL/kg, oxygen flow rate 2 L/min, inspired oxygen concentration 60%, respiratory rate 10-14 breaths/min, maintaining end-tidal carbon dioxide partial pressure at 35-45 mmHg. A warming blanket was used to maintain normal body temperature. During surgery, anesthesia was maintained with 1%-3% sevoflurane (National Drug Approval Number H20213735, 120 mL, Shanghai Hengrui Pharmaceutical), propofol (National Drug Approval Number H2013360, 50 mL:500 mg, Guangdong Jiabo Pharmaceutical) 3-6 mg/(kg·h), and remifentanil (National Drug Approval Number H20030197, 1 mg, Yichang Humanwell Pharmaceutical) 0.1-0.3 μg/(kg·min).

Anesthesia depth was adjusted according to the electroencephalographic entropy index (maintaining state entropy at 40-60), and rocuronium bromide 0.2 mg/kg was added as needed to maintain muscle relaxation. When blood pressure and heart rate fluctuations exceeded ±20% of baseline values despite adequate analgesia, corresponding vasoactive drugs were administered. At the end of surgery, after the patient regained consciousness and adequate spontaneous breathing was restored, the

endotracheal tube was removed, and the patient was transferred to the post-anesthesia care unit for continued observation. Subsequently, a patient-controlled intravenous analgesia pump was connected. the formula was sufentanil 50 μg + oliceridine 10 mg + ondansetron 8 mg, diluted to 100 mL with normal saline. the background dose was 2 mL/h, bolus dose 0.5 mL, lockout time 15 minutes.

1.5 Outcome Measures

1.5.1 Pain Indicators

VAS scores (0 points: no pain; 10 points: most severe pain) were recorded at 1-, 2-, 6-, 12-, and 24-hours postoperatively during coughing. The area under the curve (AUC) of VAS was calculated at 24 hours postoperatively, and intraoperative opioid consumption (converted to morphine milligram equivalents).

1.5.2 Block-Related Indicators

The follow indicators were recorded: block onset time (time from completion of local anesthetic injection to disappearance of needle prick pain in the surgical area), time to fixation of block plane (time from the end of the last drug injection until no change in the plane of reduced pain sensation for 2 consecutive minutes), range of block plane, procedure time (time from ultrasound localization to completion of local anesthetic injection), needle insertion depth, and patient satisfaction (5-point Likert scale, ≥4 points defined as satisfied).

1.5.3 Adverse Reactions

Incidence of complications such as bleeding at the puncture site, hematoma, nerve injury, and pneumothorax within 24 hours postoperatively were recorded.

1.6 Statistical Methods

Statistical analysis was performed using SPSS 29.0 software. Normality of measurement data was assessed by the Shapiro-Wilk test and quantile-quantile (Q-Q) plots. Measurement data conforming to normal distribution were expressed as $\overline{x}\pm s$, and intergroup comparisons were performed using independent sample t-tests. Non-inferiority testing was used for intergroup comparison of VAS scores at each time point, with the Δ value set at 1.0 point. Comparisons at multiple time points were performed using repeated measures analysis of variance, and pairwise comparisons were performed using the LSD-t test. Non-normally distributed data were expressed as $M(P_{25},P_{75})$, and intergroup comparisons were performed using the Mann-Whitney U test. Count data were expressed as case (%), and intergroup comparisons were performed using the chi-square test or corrected chi-square test. In addition, multiple linear regression (Enter method) was used to explore influencing factors, with 24-hour postoperative VAS-AUC as the dependent variable. the independent variables included age, sex (coded: male=0, female=1), BMI, block onset time, time to fixation of block plane, and range of block plane. Before regression analysis, Levene's test was used to assess homogeneity of variance. the Durbin-Watson test was used to assess residual independence, and the variance inflation factor (VIF) was calculated to assess multicollinearity. $P<0.05$ was considered statistically significant.

2 Results

2.1 Comparison of General Data

There was no statistically significant difference between the two groups in terms of age, BMI, sex, ASA classification, or smoking status ($P>0.05$). See **Table 1**.

2.2 Comparison of Postoperative VAS Scores and Intraoperative Opioid Consumption

There was no statistically significant difference between the IP group and the OOP group in the 24-h postoperative VAS-AUC (72.12±9.46 *vs* 73.77±9.35, $t=0.889$, $P=0.376$) or in intraoperative opioid consumption [54.00 (45.00, 64.00) mg *vs* 53.00 (46.00, 65.00) mg, $Z=0.177$, $P=0.859$]. Non-inferiority analysis of postoperative VAS scores showed that the upper limits of the 95% confidence intervals for the score differences between the two groups were all <1.0 point at all pre-specified time points (see **Table 2**). ANOVA revealed that the time effect and the interaction effect on postoperative VAS scores were statistically significant, whereas the group effect was not. There was no statistically significant difference between the two groups at any individual time point (see **Table 3**).

Tab.1 Comparison of general data between two groups

Indicators	IP group (n=51)	OOP group (n=51)	t/χ^2 value	P value
Age (years, $\overline{x}\pm s$)	60.33±7.60	61.22±10.32	0.492	0.624
BMI (kg/m², $\overline{x}\pm s$)	22.62±1.50	22.54±1.53	0.282	0.779
Gender (Male/Female, case)	27/24	28/23	0.039	0.843
ASA Grade I/II/III (case)	11/34/6	6/37/8	1.883	0.390
Smoking status (case)				
Still smoking	6	4	0.707	0.702
Quit smoking	31	30		
No smoking	14	17		

Tab.2 Noninferiority analysis of postoperative VAS scores between two groups

Time-point	Difference between OOP group and IP group	95%*CI*	*P*-value (non-inferiority)
1 h	-0.222	-0.472−0.029	<0.001
2 h	-0.033	-0.362−0.295	<0.001
6 h	0.316	-0.038−0.670	<0.001
12 h	0.102	-0.095−0.299	<0.001
24 h	-0.108	-0.258−0.042	<0.001

Tab.3 Comparison of postoperative VAS scores between two groups of patients (n=51,)

Group	1 hour	2 hours	6 hours	12 hours	24 hours
IP group	2.24±1.15	2.68±0.95	4.83±1.15	3.32±0.54	2.37±0.61
OOP group	1.89±0.80	2.81±0.83	4.68±1.05	3.40±0.46	2.19±0.74
$F/P_{\text{between-group}}$ value	0.020/0.887				
F/P_{time} value	237.745/<0.001				
$F/P_{\text{interaction}}$ value	2.814/0.036				

2.3 Comparison of Block-Related Indicators

Compared with the IP group, the OOP group had shorter needle insertion length and shorter procedure time (P<0.01). There was no statistically significant difference between the two groups in block onset time, time to fixed block, range of block level, or patient satisfaction (P>0.05). See **Table 4**.

2.4 Linear Regression Analysis of 24-hours Postoperative VAS-AUC

In the linear regression analysis, block onset time and time to fixed block level showed collinearity (VIF ≈ 4). To avoid collinearity masking the independent effects of the variables, model comparison was performed and the latter variable was removed to construct a more stable model. the final model (adjusted R^2=0.609) showed that range of block level, block onset time, and age were independent predictors of the 24-h postoperative VAS score (P<0.05). See **Table 5**.

2.5 Comparison of Adverse Reactions

No serious adverse reactions such as pneumothorax, local anesthetic toxicity, nerve injury, or vascular injury occurred in either group. There was no statistically significant difference between the IP group and the OOP group in the incidence of intraoperative hypotension or bradycardia.

Tab.4 Comparison of block-related indicators between two groups (n=51)

Indicators	IP group	OOP group	$Z/t/\chi^2$ value	P value
Blockade onset time [min, $M(P_{25},P_{75})$]	4.32(3.57,5.06)	4.37(3.71,5.33)	0.847	0.397
Block fixed time [min, $M(P_{25},P_{75})$]	14.42(13.56,16.04)	14.67(13.46,16.78)	0.238	0.812
Block plane range [number of segments, $M(P_{25},P_{75})$]	6.00(6.00,7.00)	6.00(5.00,7.00)	0.117	0.907
Needle insertion depth (cm, $\bar{x}\pm s$)	3.51±0.60	2.84±0.59	5.763	<0.001
Operation time (s, $\bar{x}\pm s$)	218.86±26.51	198.47±18.99	4.466	<0.001
Patient satisfaction (case)	46	48	0.543	0.461

Tab.5 Linear regression analysis of VAS-AUC 24 hours postoperatively

Indicators	Non standardized coefficient		Standardized coefficient (β)	t value	P value	VIF
	B value	SE				
Constant term	93.935	10.516		8.932	<0.001	
Block fixed range	-5.803	0.756	-0.566	-7.674	<0.001	1.406
Blockade onset time	1.975	0.494	0.278	3.998	<0.001	1.251
Age	-0.147	0.072	-0.142	-2.050	0.043	1.232

3 Discussion

TPVB is a common technique for postoperative analgesia after thoracoscopic lobectomy. Its analgesic effect is similar to that of thoracic epidural analgesia, with less puncture pain and fewer side effects [7]. Ultrasound-guided TPVB mainly includes two approaches: in-plane and out-of-plane. There is still controversy regarding the analgesic efficacy and operational efficiency of these two approaches. the results of this study show that there was no statistically significant difference between the two approaches in terms of block onset time, time to fixation of block plane, range of block plane, VAS scores at various postoperative time points, and incidence of adverse reactions. This result is consistent with the conclusion of a previous study [9] that observed no statistically significant difference in drug diffusion range between the two approaches. It should be noted that the block success rate in this study reached 100%, which is attributed to the use of a clinical operational definition based on sensory blockade of at least two dermatomes [10]. If anatomical diffusion criteria were used instead, the results might differ.

Regarding operational parameters, compared with the in-plane approach, the out-of-plane approach had a shorter procedure time and shallower needle insertion depth. This finding is consistent with the conclusion of a previous study [8] conducted under conditions with needle guidance, suggesting that the out-of-plane approach may have an advantage in operational efficiency. No serious complications such as pneumothorax or vascular puncture occurred in either group, reflecting the safety of ultrasound-guided TPVB [11]. However, both approaches have learning curves, whether it is visualizing the entire needle in the in-plane approach or accurately identifying the needle tip in the out-of-plane approach [1,12]. Therefore, in clinical practice, it is necessary to be familiar with the anatomical layers, use the "hydrodissection" technique to confirm needle tip position, and strictly adhere to safe needle insertion distances [13]. Although the in-plane approach is more widely used due to full visualization of the needle trajectory, the out-of-plane approach may have advantages for obese patients or those with specific anatomical conditions [14]. It is recommended that clinicians master both techniques and flexibly choose according to the actual situation.

Given that the analgesic effect of the out-of-plane approach is non-inferior to that of the in-plane approach, this study further performed multiple linear regression analysis with the 24-hour postoperative VAS-AUC as the dependent variable. the results showed that the range of block plane, time to fixation of block plane, and age were independent influencing factors for postoperative pain. Among these, the range of block plane was the factor contributing the most to the regression model, which is consistent with its anatomical basis: an adequate block range is a prerequisite for covering the surgical incision

and afferent pain pathways [15]. However, a wider block range is not necessarily better; excessive spread may increase the risk of complications without additional benefit. At the same time, the negative correlation trend between age and pain scores observed in this study is similar to findings from large cohort studies [16], which may partially reflect age-related changes in pain threshold. However, this association is weak, and clinical attention to analgesia in elderly patients should not be reduced on this basis. During the modeling process, the authors found collinearity between block onset time and block duration. After considering variable independence and model interpretability, removing time to fixation of block plane was most beneficial for model optimization. Previous studies have suggested that BMI may influence postoperative pain scores after TPVB [17], but that study included a wider BMI range (18-40 kg/m²), which may explain why no significant association was observed in the present study. Future studies need to expand the BMI range for verification. This study has the following limitations. First, the sample size is relatively small, and the enrolled patient population and surgical types are limited, which may affect statistical power and limit the generalizability of the results. Second, the assessment of pain and analgesic effects relied primarily on patient subjective reports, introducing a risk of measurement bias. More importantly, there is currently no gold standard for evaluating the effect of nerve blocks [18]. Although the cold sensation test used in this study is widely applied, its results depend on patients' subjective feelings, and because cold sensation and pain are mediated by different nerve fibers [19], and evidence suggests that low-concentration local anesthetics may preferentially block C fibers that mediate pain [20], this test may not accurately reflect the degree of pain blockade, thus carrying a risk of underestimating the analgesic effect. Third, the study only focused on short-term postoperative outcomes and lacked long-term follow-up data. Future larger-scale, multicenter prospective studies using more objective assessment indicators and longer follow-up periods are needed.

In summary, this study demonstrates that the in-plane and out-of-plane approaches for TPVB have equivalent analgesic effects. the range of block plane, onset time, and age are independent influencing factors for postoperative analgesic effect and have certain predictive value. Therefore, clinicians should master both techniques and flexibly choose based on individual patient conditions.

Conflict of Interest None

References

[1] Hoogma DF, Brullot L, Coppens S. Get your 7-point golden medal for pain management in video-assisted thoracoscopic surgery[J]. Curr Opin Anaesthesiol, 2024, 37(1): 64-68.
[2] Ma T, Yu YL, Cao HH, et al. Effect of intermittent thoracic paravertebral block on postoperative nausea and vomiting following thoracoscopic radical resection of the lung cancer: a prospective randomized trial[J]. J Pain Res, 2024, 17: 931-939.
[3] Huang YB, Wang MF, He T, et al. Effects of nerve block in different areas on opiate dosage and stress response in patients undergoing thoracoscopic radical resection of lung cancer [J]. Chin J Clin Res, 2024, 37(1): 61-65. **[In Chinese]**
[4] Zhu JY, Wei BY, Wu LL, et al. Effect of thoracic paravertebral block on postoperative pulmonary complications after video-assis ted thoracoscopic surgery: a dual-center randomized clinical trial [J]. Ther Clin Risk Manag, 2025, 21: 691-703.
[5] Ali Kaçar M, Çiçekci F, Uluer MS, et al. Comparison of caudal epidural block using out-of-plane and in-plane techniques with ultrasound in pediatric hypospadias surgery: a prospective rando mized clinical study[J]. Genel Tıp Dergisi, 2025, 35(2): 319-324.
[6] Samir GM, Ghallab MAE. Onset and recovery of ultrasound guided out-of-plane versus in-plane interscalene block in arthroscopic shoulder surgery[J]. Ain Shams J Anesthesiol, 2020, 12(1): 16.
[7] Zhang YC, Sun Y, Li SH, et al. Clinical effects, mechanisms and spread of erector spinae plane block and paravertebral block in thoracic and breast surgery: a narrative review[J]. Int J Surg, 2025, 111(12): 9507-9519.
[8] Li D, Cheng YC, Yuan P, et al. Efficacy and safety of flurbiprofen cataplasms versus loxoprofen sodium cataplasms in knee osteoarthritis: a randomized controlled trial[J]. Chin Med J, 2023, 136 (18): 2187-2194.
[9] Ruscio L, Renard R, Lebacle C, et al. Thoracic paravertebral block: comparison of different approaches and techniques. A study on 27 human cadavers[J]. Anaesth Crit Care Pain Med, 2020, 39 (1): 53-58.
[10] Tong Y, Wu JM, Wu XH, et al. Analgesic efficacy of thoracoscopic direct-view versus ultrasound-guided thoracic paravertebral block in multi-port video-assisted thoracoscopic lung surgery: a randomized controlled non-inferiority study[J]. Drug Des Devel Ther, 2025, 19: 1825-1838.
[11] Meiser VC, Kreysa H, Guntinas-Lichius O, et al. Comparison of inplane and out-of-plane needle insertion with vs without needle guidance[J]. Eur Arch Otorhinolaryngol, 2016, 273(9): 2697-2705.
[12] Sites BD, Brull R, Chan VWS, et al. Artifacts and pitfall errors associated with ultrasound-guided regional anesthesia. Part I: understanding the basic principles of ultrasound physics and machine operations[J]. Reg Anesth Pain Med, 2007, 32(5): 412-418.
[13] Jones A, Le-Wendling L, Ihnatsenka B, et al. Empirical guide to a safe thoracic paravertebral block based on dimensions of paravertebral space when ultrasound visualization is challenging[J]. Reg Anesth Pain Med, 2024, 49(2): 133-138.
[14] Kim EJ, Min J, Song J, et al. the effect of electromagnetic guidance system on early learning curve of ultrasound for novices[J]. Korean J Anesthesiol, 2016, 69(1): 15-20.
[15] D'Ercole F, Arora H, Kumar PA. Paravertebral block for thoracic surgery[J]. J Cardiothorac Vasc Anesth, 2018, 32(2): 915-927.
[16] Kim JH, Sohn JH, Lee JJ, et al. Age-related variations in postoperative pain intensity across 10 surgical procedures: a retrospective study of five hospitals in South Korea[J]. J Clin Med, 2023, 12 (18): 5912.
[17] Zengin EN, Alagöz A, Yigit H, et al. the effect of body mass index on thoracic paravertebral block analgesia after video-assisted thoracoscopic surgery;a prospective interventional study[J]. BMC Anesthesiol, 2023, 23(1): 297.
[18] Zhang S, Liu Y, Liu XH, et al. Infrared thermography for assessment of thoracic paravertebral block: a prospective observational study[J]. BMC Anesthesiol, 2021, 21(1): 168.
[19] Buijs TJ, McNaughton PA. the role of cold-sensitive ion channels in peripheral thermosensation[J]. Front Cell Neurosci, 2020, 14: 262.
[20] Shan T, Zhang XD, Zhao ZY, et al. Spread of local anaesthetic after erector spinae plane block: a randomised, three-dimensional reconstruction, imaging study[J]. Br J Anaesth, 2025, 134(3): 830-838

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·临床麻醉专题·论著·

两点法不同入路胸椎旁神经阻滞的镇痛效果

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摘要：目的 比较超声引导下胸椎旁神经阻滞(TPVB)平面内与平面外入路对胸腔镜肺叶切除术患者术后镇痛效果的差异。**方法** 采用随机对照试验设计，纳入2025年1月至8月于山东大学齐鲁第二医院择期行胸腔镜肺叶切除术患者102例，随机分为平面内组(IP组，n=51)与平面外组(OOP组，n=51)。所有患者于术前在麻醉准备间接受超声引导下单次TPVB。主要观察指标为术后6 h咳嗽时视觉模拟评分(VAS)。次要指标包括术后1、2、12、24 h的咳嗽VAS评分、术后24 h VAS的曲线下面积(AUC)、阻滞操作时间、进针深度、阻滞起效与固定时间、阻滞平面范围、术中阿片类药物消耗量、患者满意度及不良反应。采用多元线性回归分析术后24 h VAS-AUC的影响因素。**结果** 两组患者在术后各时点VAS评分、24 h VAS-AUC、术中阿片类药物用量、患者满意度及术中不良反应发生率上差异均无统计学意义(P>0.05)。与IP组比较，OOP组有更短的操作时间[194.00(181.00, 217.00)s *vs* 227.00(201.00, 259.50)s, Z=4.803, P<0.01]和更浅的进针深度[2.80(2.30, 3.40) cm *vs* 3.50 (3.00, 4.00)m, Z=4.854, P<0.01]。多元线性回归分析显示，阻滞平面范围、阻滞起效时间及年龄是术后疼痛的独立影响因素(P<0.05)。**结论** 对于胸腔镜肺叶切除术，超声引导TPVB采用平面外入路可提供与平面内入路相近的术后镇痛效果，且具有操作更便捷、进针更浅的优势。而阻滞范围、阻滞起效时间及患者年龄是影响平面外入路TPVB镇痛效果的关键因素。

关键词： 超声引导；视频辅助胸腔镜手术；胸椎旁神经阻滞；术后镇痛；平面内入路；平面外入路
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Analgesic effects of different approaches for two-point thoracic paravertebral block

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Abstract: Objective To compare the postoperative analgesic efficacy of the in-plane versus out-of-plane approach for ultrasound-guided thoracic paravertebral block (TPVB) in patients undergoing thoracoscopic lobectomy. **Methods** A total of 102 patients scheduled for elective thoracoscopic lobectomy at Qilu Second Hospital of Shandong University from January to August 2025 were enrolled and randomly divided into an in-plane group (IP group, n=51) and an out-of-plane group (OOP group, n=51). All patients received a single-shot ultrasound-guided TPVB in the anesthesia preparation room before surgery. The primary outcome measure was the Visual Analogue Scale (VAS) score at 6 hours postoperatively. Secondary outcomes included cough VAS scores at 1, 2, 12, and 24 hours postoperatively, area under the curve (AUC) of VAS 24 hours postoperatively, block performance time, needling depth, block onset and fixation time, extent of sensory block, intraoperative opioid consumption, patient satisfaction, and adverse reactions. Multivariate linear regression was used to analyze factors influencing the VAS-AUC at 24 hours postoperatively. **Results** There was no statistically significant difference between the two groups in VAS scores at various postoperative time points, 24-hour VAS-AUC, intraoperative opioid consumption, patient satisfaction, or incidence of intraoperative adverse reactions (P>0.05). Compared with the IP group, the OOP group had a significantly shorter block performance time [194.00(181.00, 217.00)s *vs* 227.00(201.00, 259.50)s, Z=4.803, P<0.01] and shallower needling depth [2.80(2.30, 3.40) cm *vs* 3.50

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(3.00, 4.00) m, Z=4.854, P<0.01]. Multivariate linear regression analysis showed that sensory block extent, block onset time, and age were independent influencing factors of postoperative pain (P<0.05). **Conclusion** For thoracoscopic lobectomy, the out-of-plane approach for ultrasound-guided TPVB provides comparable postoperative analgesia to the in-plane approach, while offering the advantages of being more convenient to perform and requiring a shallower needling depth. The extent of sensory block, onset time block, and patient age are key factors influencing the analgesic efficacy of the out-of-plane TPVB approach.

Keywords: Ultrasound-guided; Video-assisted thoracoscopic surgery; Thoracic paravertebral block; Postoperative analgesia; In-plane approach; Out-of-plane approach

视频辅助胸腔镜手术(video-assisted thoracoscopic surgery,VATS)已成为肺癌的主要微创治疗手段。然而,患者术后仍常伴随剧烈且持久的疼痛,这不仅妨碍呼吸功能恢复,也增加了肺部感染、肺不张等并发症风险[1]。胸椎旁神经阻滞(thoracic paravertebral block,TPVB)是胸科手术术后多模式镇痛的首选区域麻醉技术之一[2]。它通过阻断手术区域痛觉传导,能有效缓解疼痛,减少阿片类药物用量,并降低术后恶心呕吐(postoperative nausea and vomiting,PONV)、谵妄及肺部并发症的发生率[3-4]。超声引导技术的应用,使椎旁间隙的显影更为清晰,显著提升了TPVB穿刺的准确性与安全性[5]。目前,超声引导下TPVB根据穿刺针轨迹与超声声束平面的关系,主要分为平面内与平面外两种入路,但二者在临床镇痛效果与阻滞效能方面仍存在争议[6-7]。本研究旨在比较超声引导下平面内与平面外TPVB用于VATS术后的镇痛效果及操作相关指标,并通过线性回归分析术后疼痛评分的影响因素,以期为胸科手术患者优化TPVB入路选择与镇痛方案提供临床依据。

1　资料与方法

1.1　一般资料　本研究为前瞻性研究。选取2025年1月至2025年8月在山东大学附属齐鲁第二医院择期行单孔胸腔镜肺叶切除术的患者。纳入标准:(1)年龄18~80岁;(2)身体质量指数(body mass index,BMI)18.5~28.0 kg/m^2;(3)美国麻醉医师协会(American Society of Anesthesiologists,ASA)分级Ⅰ~Ⅲ级;(4)拟择期行单孔胸腔镜肺叶切除术。排除标准:(1)拒绝参与研究或无法签署知情同意书;(2)患有未经控制的严重精神神经系统疾病,或长期服用相关药物;(3)存在认知功能障碍或严重感官、语言障碍,无法交流评估;(4)术前3个月内存在中重度慢性疼痛[视觉模拟评分(Visual Analogue Scale,VAS)≥4分]或规律使用镇痛药;(5)有药物(特别是阿片类)或酒精滥用史;(6)穿刺部位存在活动性感染或全身性活动性感染;(7)凝血功能明显异常;(8)合并严重且未控制的系统性疾病(如心、肝、肾功能不全);(9)存在严重脊柱畸形或同侧胸部手术史;(10)对罗哌卡因等局麻药过敏;(11)妊娠或哺乳期妇女;(12)术中转开胸手术或发生严重并发症。本研究经山东大学齐鲁第二医院科研伦理委员会批准(审批号:KYLL2025016)。

1.2　样本量计算及分组　使用PASS 21软件估计样本量。以术后6 h咳嗽时的VAS为主要终点。根据预试验数据及临床意义,设定非劣效性界值(Δ值)为1.0分[8],OOP组VAS评分为(4.0±1.0)分,IP组为(4.4±0.9)分。设定单侧检验水准α=0.025,把握度为80%。经计算,每组至少需要43例患者。考虑脱落率为20%,每组计划招募纳入54例,合计样本量需纳入108例受试者。108例患者按照随机数字表法随机分配到平面外入路组(OOP组,n=54)或平面内入路组(IP组,n=54)。试验过程中,共有6例患者脱落:其中1例术中转为开放式手术,1例撤销知情同意,4例失访。最终,OOP组和IP组各有51例患者完成了本试验并被纳入最终分析。

1.3　超声引导下TPVB　患者于术前1小时进入麻醉准备间,建立静脉通路,并于桡动脉穿刺置管前行局部浸润麻醉。随后,患者取健侧卧位(手术侧朝上),静脉注射咪达唑仑0.02 mg/kg(国药准字H19990027,规格1 mL∶5 mg,江苏恩华药业)镇静后,行超声引导下两点法TPVB。采用2~5 MHz低频凸阵探头,首先于矢状位识别C_7棘突并尾侧扫描,根据手术区域确定两个目标阻滞节段(T_4与T_7)。每个节段按下述分组策略进行穿刺:IP组将探头旋转90°置于棘突旁约2.5 cm获取横轴位图像,阻滞针在超声平面内由外侧进针,全程可视下穿透上位肋横突上韧带(superior costotransverse ligament,SCTL)进入胸椎旁间隙(paravertebral space,PVS);OOP组则保持探头矢状位并外移,直至同时显示相邻横突、SCTL及胸膜,阻滞针垂直于探头长轴方向进针,通过微调探头追踪针尖使

其突破SCTL进入PVS。穿刺到位后，均先行负压回抽，回抽无血及脑脊液后，随后注入2~3 mL 0.9%氯化钠溶液，在超声实时确认胸膜向腹侧移位、PVS增宽后，于每个节段分次注射0.33%罗哌卡因15 mL，并观察药液扩散及胸膜下移情况。

1.4 麻醉方法 进入手术室后，所有患者持续监测外周血氧饱和度、心电图、心率、有创血压、体温和熵指数。麻醉诱导：静脉注射舒芬太尼（国药准字H20054171，规格1 mL∶50 μg，宜昌人福药业）0.5 μg/kg，丙泊酚（国药准字HJ20150654，规格20 mL∶200 mg，奥地利费森尤斯卡比）1.5~2.5 mg/kg与罗库溴铵（国药准字 H20213778，规格5 mL∶50 mg，广东星昊药业）0.8 mg/kg。待患者意识消失、肌肉松弛满意后行气管内插管并机械通气，潮气量设为8~10 mL/kg，氧流量2 L/min，吸入氧浓度60%，呼吸频率10~14次/min，维持呼气末二氧化碳分压35~45 mmHg。采用保温毯加温，保持正常体温。术中通过1%~3%的七氟烷（国药准字H20213735，规格120 mL，上海恒瑞医药）、丙泊酚（国药准字H2013360，规格50 mL∶500 mg，广东嘉博制药）3~6 mg/(kg·h)和瑞芬太尼（国药准字H20030197，规格1 mg，宜昌人福药业）0.1~0.3 μg/(kg·min)维持麻醉。根据脑电熵指数（维持状态熵40~60）调整麻醉深度，按需追加罗库溴铵0.2 mg/kg维持肌肉松弛。当镇痛充分时血压、心率波动幅度仍超过基础值20%时，给予相应血管活性药。术毕待患者意识清醒、自主呼吸恢复良好后，拔除气管导管，入恢复室继续观察。随后连接静脉自控镇痛泵，配方为舒芬太尼50 μg + 奥赛利定10 mg+昂丹司琼8 mg，生理盐水稀释至100 mL，背景剂量2 mL/h，单次按压剂量0.5 mL，锁定时间15 min。

1.5 结局指标

1.5.1 疼痛指标 记录术后咳嗽时1、2、6、12、24 h VAS评分（0分：无痛；10分：最剧烈疼痛），计算术后24 h VAS曲线下面积（area under curve，AUC）、术中阿片类用量（换算为吗啡毫克当量）。

1.5.2 阻滞相关指标 记录阻滞起效时间（从局麻药注射完毕至手术区域针刺痛觉消失的时间）、阻滞平面固定时间（末次注药结束至痛觉减退平面连续2 min无变化所需时长）、阻滞平面范围、操作时间（从超声定位开始至局麻药注射完毕的时间）、进针深度及患者满意度（5分Likert量表，≥4分定义为满意）。

1.5.3 不良反应 记录术后24 h内穿刺部位出血、血肿、神经损伤、气胸等并发症发生情况。

1.6 统计学方法 采用SPSS 29.0软件进行统计分析。计量资料经Shapiro-Wilk检验及分位数-分位数图（quantile-quantile plot，Q-Q图）评估正态性。符合正态分布的计量资料以$\bar{x}\pm s$表示，组间比较采用独立样本t检验；对各时点的VAS评分采用非劣效性检验进行组间比较，设定Δ值为1.0分；多时点比较采用重复测量方差分析，两两比较采用LSD-t检验。非正态分布的计量资料以$M(P_{25},P_{75})$表示，组间比较采用Mann-Whitney U检验。计数资料以例（%）表示，组间比较采用χ^2检验或校正χ^2检验。此外，采用多元线性回归（Enter法）探讨影响因素，以术后24 h VAS-AUC为因变量，纳入的自变量包括年龄、性别（赋值：男=0，女=1）、BMI、阻滞起效时间、阻滞平面固定时间及阻滞平面范围。回归分析前使用Levene检验评估方差齐性。使用Durbin-Watson检验评估残差独立性，计算方差扩大因子（variance inflation factor，VIF）评估多重共线性。P<0.05为差异有统计学意义。

2 结 果

2.1 一般资料比较 两组患者的年龄、BMI、性别、ASA分级及吸烟状态比较，差异均无统计学意义（P>0.05）。见表1。

2.2 两组患者术后VAS评分及术中阿片类物用量比较 IP组与OOP组术后24 h VAS-AUC（72.12 ± 9.46 *vs* 73.77 ± 9.35，t=0.889，P=0.376）及术中阿片类药物用量[54.00(45.00，64.00)mg *vs* 53.00 (46.00，65.00) mg，Z=0.177，P=0.859]的差异均无统计学意义。对术后VAS评分的非劣效性分析结果显示，在所有预设时间点，两组评分差值的95%CI上限均<1.0分，见表2。重复测量方差分析结果显示术后VAS评分的时间效应和交互相应有统计学意义，而组间效应无统计学意义，同时间点两组间比较差异均无统计学意义，见表3。

2.3 两组患者阻滞相关指标比较 与IP组相比，OOP组的进针长度与操作时间更短（P<0.01）。两组在阻滞起效时间、阻滞固定时间、阻滞平面范围及患者满意度方面的差异均无统计学意义（P>0.05）。见表4。

2.4 术后24 h VAS-AUC的线性回归分析 在线性回归分析中，阻滞起效时间与阻滞平面固定时间存在共线性（VIF≈4），为避免共线性掩盖变量的独立效应，进行了模型比较并剔除了后者以构建更稳定的模型。最终模型（调整后R^2=0.609）显示，阻滞平面范围、阻滞起效时间及年龄是术后24 h VAS评分的独立预测因素（P<0.05）。见表5。

2.5　两组不良反应发生情况比较　两组均未发生气胸、局部麻醉药中毒、神经损伤或血管损伤等严重不良反应。IP 组与 OOP 组的术中低血压[11.76%(6/51) *vs* 9.80%(5/51), χ^2=0.378, *P*=0.760]、PONV[7.84%(4/51) *vs* 5.88%(3/51), χ^2=0.153, *P*=0.695]和心动过缓[9.80%(5/51) *vs* 13.73%(7/51), χ^2=0.102, *P*=0.750]的发生率差异均无统计学意义。

表 1　两组患者一般资料比较　(*n*=51)

Tab.1　Comparison of general data between two groups　(*n*=51)

指标	IP组	OOP组	t/χ^2值	*P*值
年龄(岁, $\bar{x}\pm s$)	60.33±7.60	61.22±10.32	0.492	0.624
BMI(kg/m^2, $\bar{x}\pm s$)	22.62±1.50	22.54±1.53	0.282	0.779
性别(男/女,例)	27/24	28/23	0.039	0.843
ASA Ⅰ/Ⅱ/Ⅲ级(例)	11/34/6	6/37/8	1.883	0.390
吸烟状态(例)				
仍在吸烟	6	4		
戒烟	31	30	0.707	0.702
不吸烟	14	17		

表 2　两组术后 VAS 评分非劣效性分析　(n=51, $\bar{x}\pm s$)

Tab.2　Non-inferiority analysis of postoperative VAS scores between two groups　(n=51, $\bar{x}\pm s$)

时点	OOP组与IP组差值	95%*CI*	*P*值(非劣效性)
1 h	−0.222	−0.472~0.029	<0.001
2 h	−0.033	−0.362~0.295	<0.001
6 h	0.316	−0.038~0.670	<0.001
12 h	0.102	−0.095~0.299	<0.001
24 h	−0.108	−0.258~0.042	<0.001

表 3　两组患者术后 VAS 评分比较　(n=51, $\bar{x}\pm s$)

Tab.3　Comparison of postoperative VAS scores between two groups of patients　(n=51, $\bar{x}\pm s$)

组别	1 h	2 h	6 h	12 h	24 h
IP组	2.24±1.15	2.68±0.95	4.83±1.15	3.32±0.54	2.37±0.61
OOP组	1.89±0.80	2.81±0.83	4.68±1.05	3.40±0.46	2.19±0.74
$F/P_{组间}$值	0.020/0.887				
$F/P_{时间}$值	237.745/<0.001				
$F/P_{交互}$值	2.814/0.036				

表 4　两组患者阻滞相关指标比较　(n=51)

Tab.4　Comparison of block-related indicators between two groups　(n=51)

项目	IP组	OOP组	Z/χ^2值	*P*值
阻滞起效时间(min)[a]	4.32(3.57,5.06)	4.37(3.71,5.33)	0.847	0.397
阻滞固定时间(min)[a]	14.42(13.56,16.04)	14.67(13.46,16.78)	0.238	0.812
阻滞平面范围(节段数)[a]	6.00(6.00,7.00)	6.00(5.50,7.00)	0.117	0.907
进针深度(cm)[a]	3.50(3.00, 4.00)	2.80(2.30,3.40)	4.854	<0.001
操作时间(s)[a]	227.00(201.00,259.50)	194.00(181.00,217.00)	4.803	<0.001
患者满意度(例)	46	48	0.543	0.461

注:[a]为数据以 $M(P_{25},P_{75})$表示。

表 5　术后 24 h VAS-AUC 的线性回归分析

Tab.5　Linear regression analysis of VAS-AUC 24 hours postoperatively

项目	非标准化系数		标准化系数(β)	*t*值	*P*值	VIF
	*B*值	*SE*				
常数项	93.935	10.516		8.932	<0.001	
阻滞平面范围	−5.803	0.756	−0.566	−7.674	<0.001	1.406
阻滞起效时间	1.975	0.494	0.278	3.998	<0.001	1.251
年龄	−0.147	0.072	−0.142	−2.050	0.043	1.232

3　讨　论

TPVB 是胸腔镜肺叶切术术后镇痛的常用技术，其镇痛效果与胸椎硬膜外镇痛相近，且穿刺痛更轻、副作用更少[7]。超声引导 TPVB 主要包括平面内与平面外两种入路，关于二者的镇痛效果与操作效率仍存在争议。本研究结果显示，两种入路在阻滞起效时间、阻滞平面固定时间、阻滞平面范围、术后各时点 VAS 评分及不良反应发生率差异无统计学意义。该结果与既往研究[9]中观察到的两种入路在药物扩散范围上差异无统计学意义的结论一致。需要说明的是，本研究中阻滞成功率达 100%，这源于本研究中采用了基于至少两个皮节感觉阻滞的临床操作定义[10]。若参照解剖学扩散标准，结果可能有所不同。

在操作参数方面，与平面内入路相比，平面外入路的操作时间较短且进针深度较浅。这一发现与先前研究[8]在有针导条件下得出的结论相符，即平面外入路可能更具操作效率优势。两组均未出现气胸、血管误穿等严重并发症，体现了超声引导 TPVB 的安全性[11]。然而，无论是平面内入路中全程显示针体，还是平面外入路中准确辨识针尖，均存在学习曲线[12]，因此，临床实践中需熟悉解剖层次，运用“水分离”技术确认针尖位置，并严格把握进针安全距离[13]，尽管平面内入路因针迹全程可视而应用更广，但平面外入路对肥胖患者或特定解剖条件者可能更具优势[14]。建议临床医师掌握两种技术，依据实际情况灵活选用。

鉴于平面外入路的镇痛效果非劣于平面内路，本研究进一步以术后 24 h VAS-AUC 为因变量进行多

元线性回归分析。结果显示，阻滞平面范围、阻滞固定时间及年龄是术后疼痛的独立影响因素，其中，阻滞平面范围是回归模型中贡献最大的因素，这符合其解剖学基础：足够的阻滞范围是覆盖手术切口与内脏痛传入通路的前提[15]。然而，阻滞范围并非越广越好，过度扩散可能增加并发症风险而不带来额外获益。同时，本研究中年龄与疼痛评分的负相关趋势，与大型队列研究观察到的结论相似[16]，可能部分反映年龄相关的痛觉阈值变化，但该关联较弱，临床中不应因此降低对老年患者的镇痛关注。在建模过程中，笔者发现阻滞起效时间与持续时间存在共线性，在考虑变量独立性及模型解释度后，剔除阻滞固定时间对模型的优化最为有利。既往有研究提示 BMI 可能影响 TPVB 术后疼痛评分[17]，但该研究纳入的 BMI 范围较宽（18~40 kg/m^2），这可能是本研究未观察到显著关联的原因，未来需扩大 BMI 范围加以验证。

本研究存在以下局限性。首先，样本量较小且纳入患者群体及手术类型较为局限，可能影响统计效力并限制结果外推性。其次，主要依赖患者主观报告评估疼痛与镇痛效果，存在测量偏倚风险。尤为重要的是，目前评估神经阻滞效果缺乏金标准[18]；本研究采用的冷觉测试虽广泛应用，但其结果依赖患者主观感受，且由于冷觉与痛觉由不同神经纤维介导[19]，加之有证据表明低浓度局麻药可能优先阻断介导痛觉的 C 纤维[20]，该测试可能无法准确反映痛觉阻滞程度，从而存在低估镇痛效果的风险。再者，研究仅关注短期术后结局，缺乏长期随访数据。未来需要通过更大规模、多中心的前瞻性研究，采用更客观的评估指标与更长的随访时间。

综上所述，本研究表明，TPVB 的平面内与平面外入路镇痛效果等效。阻滞平面范围、起效时间及年龄是术后镇痛效果的独立影响因素，具有一定的预测价值。因此，临床医师应熟练掌握这两种技术，并依据患者个体情况灵活选用。

利益冲突　无

参考文献

[1] Hoogma DF, Brullot L, Coppens S. Get your 7-point golden medal for pain management in video-assisted thoracoscopic surgery[J]. Curr Opin Anaesthesiol, 2024, 37(1): 64-68.

[2] Ma T, Yu YL, Cao HH, et al. Effect of intermittent thoracic paravertebral block on postoperative nausea and vomiting following thoracoscopic radical resection of the lung cancer: a prospective randomized trial[J]. J Pain Res, 2024, 17: 931-939.

[3] 黄益波，王梅芳，贺腾，等. 不同区域神经阻滞对胸腔镜肺癌根治术患者阿片类药物用量和应激反应的影响[J]. 中国临床研究，2024，37(1)：61-65.

[4] Zhu JY, Wei BY, Wu LL, et al. Effect of thoracic paravertebral block on postoperative pulmonary complications after video-assisted thoracoscopic surgery: a dual-center randomized clinical trial[J]. Ther Clin Risk Manag, 2025, 21: 691-703.

[5] Ali Kaçar M, Çiçekci F, Uluer MS, et al. Comparison of caudal epidural block using out-of-plane and in-plane techniques with ultrasound in pediatric hypospadias surgery: a prospective randomized clinical study[J]. Genel Tıp Dergisi, 2025, 35(2): 319-324.

[6] Samir GM, Ghallab MAE. Onset and recovery of ultrasound guided out-of-plane versus in-plane interscalene block in arthroscopic shoulder surgery[J]. Ain Shams J Anesthesiol, 2020, 12(1): 16.

[7] Zhang YC, Sun Y, Li SH, et al. Clinical effects, mechanisms and spread of erector spinae plane block and paravertebral block in thoracic and breast surgery: a narrative review[J]. Int J Surg, 2025, 111(12): 9507-9519.

[8] Li D, Cheng YC, Yuan P, et al. Efficacy and safety of flurbiprofen cataplasms versus loxoprofen sodium cataplasms in knee osteoarthritis: a randomized controlled trial[J]. Chin Med J, 2023, 136(18): 2187-2194.

[9] Ruscio L, Renard R, Lebacle C, et al. Thoracic paravertebral block: comparison of different approaches and techniques. A study on 27 human cadavers[J]. Anaesth Crit Care Pain Med, 2020, 39(1): 53-58.

[10] Tong Y, Wu JM, Wu XH, et al. Analgesic efficacy of thoracoscopic direct-view versus ultrasound-guided thoracic paravertebral block in multi-port video-assisted thoracoscopic lung surgery: a randomized controlled non-inferiority study[J]. Drug Des Devel Ther, 2025, 19: 1825-1838.

[11] Meiser VC, Kreysa H, Guntinas-Lichius O, et al. Comparison of in-plane and out-of-plane needle insertion with *vs* without needle guidance[J]. Eur Arch Otorhinolaryngol, 2016, 273(9): 2697-2705.

[12] Sites BD, Brull R, Chan VWS, et al. Artifacts and pitfall errors associated with ultrasound-guided regional anesthesia. Part I: understanding the basic principles of ultrasound physics and machine operations[J]. Reg Anesth Pain Med, 2007, 32(5): 412-418.

[13] Jones A, Le-Wendling L, Ihnatsenka B, et al. Empirical guide to a safe thoracic paravertebral block based on dimensions of paravertebral space when ultrasound visualization is challenging[J]. Reg Anesth Pain Med, 2024, 49(2): 133-138.

[14] Kim EJ, Min J, Song J, et al. The effect of electromagnetic guidance system on early learning curve of ultrasound for novices[J]. Korean J Anesthesiol, 2016, 69(1): 15-20.

[15] D'Ercole F, Arora H, Kumar PA. Paravertebral block for thoracic surgery[J]. J Cardiothorac Vasc Anesth, 2018, 32(2): 915-927.

[16] Kim JH, Sohn JH, Lee JJ, et al. Age-related variations in postoperative pain intensity across 10 surgical procedures: a retrospective study of five hospitals in South Korea[J]. J Clin Med, 2023, 12(18): 5912.

[17] Zengin EN, Alagöz A, Yiğit H, et al. The effect of body mass index on thoracic paravertebral block analgesia after video-assisted thoracoscopic surgery; a prospective interventional study[J]. BMC Anesthesiol, 2023, 23(1): 297.

[18] Zhang S, Liu Y, Liu XH, et al. Infrared thermography for assessment of thoracic paravertebral block: a prospective observational study[J]. BMC Anesthesiol, 2021, 21(1): 168.

[19] Buijs TJ, McNaughton PA. The role of cold-sensitive ion channels in peripheral thermosensation[J]. Front Cell Neurosci, 2020, 14: 262.

[20] Shan T, Zhang XD, Zhao ZY, et al. Spread of local anaesthetic after erector spinae plane block: a randomised, three-dimensional reconstruction, imaging study[J]. Br J Anaesth, 2025, 134(3): 830-838.

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