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Distribution pattern of different volumes of ropivacaine in ultrasound-guided intertransverse process block: a randomized, blinded, computed tomography imaging study

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Abstract

Background Intertransverse process (ITP) blocks showed reliable paravertebral spread in cadaveric studies, but specific distribution patterns, spread pathways, and dose–effect relationships remain unclear. The aim of this study was to evaluate the distribution patterns of three different volumes of local anesthetic (LA) in ITP block in living humans using computed tomography.

Methods Forty-five individuals (18–75 years old) were randomized to receive 0.375% ropivacaine with radiopaque contrast agent at doses of 0.3, 0.4, or 0.5 ml/kg. The primary outcome was the distribution of LA in mediastinal compartments (prevascular, visceral, and paravertebral), retro-superior costotransverse ligament space, erector spinae fascia plane, intercostal space, sympathetic ganglion, costotransverse space, intervertebral foramen, lateral recess, and epidural space. The secondary outcomes included intraoperative and postoperative VAS scores, dermatomal sensory loss, block-related adverse events, and the time required for block administration.

Results The spread pattern of local anesthetic after intertransverse process block includes both forward and backward spread. The LA was concentrated in the visceral compartment (77.5%), paravertebral compartment (93.3%), erector spinae fascia plane (97.8%), intercostal space (97.8%), and sympathetic ganglion (88.9%), with occasional spread to other areas. The overall distribution pattern was significantly influenced by patient position ($R^2 = 0.07$, F. Model = 3.43, $P = 0.04$) rather than anesthetic volume ($R^2 = 0.03$, F. Model = 1.60, $P = 0.20$) and BMI category ($R^2 = 0.03$, F. Model = 1.36, $P = 0.26$). The LA was concentrated in the prevascular compartment when the patient position was changed in the prone position (B = 2.45, 95% CI [0.96, 3.95], $P = 0.002$). There were no differences in secondary outcomes.

Conclusions ITP block causes the LA to predominantly spread to the paravertebral compartment, visceral compartment, intercostal space, sympathetic ganglion, and erector spinae fascia plane. Within the range of volumes studied (0.3, 0.4, and 0.5 ml/kg), increasing the LA volume did not result in a wider distribution range; the overall distribution pattern was primarily influenced by patient positioning.

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Keywords Ultrasonography, Anesthesia, Local, Tomography, X-Ray Computed, Intertransverse process block, Paravertebral block

Background

Intertransverse Process (ITP) block is a novel "paravertebral-by-proxy" block that targets the retro-superior costotransverse ligament space or the midpoint between the transverse process and pleura [1]. Since its initial description by Costache et al. [2] in 2017, various similar techniques have reported [3–5]. International consensus collectively refers to these techniques as ITP block [1], including the midpoint transverse process to pleura (MTP) block [2], sub-transverse process interligamentary plane (STIL) block [4], costotransverse foramen (CTF) block [3], and multiple injection costotransverse (MIC) block [5].

Cadaveric studies have demonstrated that ITP block achieves more anterior spread of local anesthetic (LA) compared to erector spinae plane (ESP) block [6]. A micro-computed tomography (CT) study revealed that the retro-superior costotransverse ligament space may represent an important connection between the paravertebral space and intercostal space through the medial and lateral superior costotransverse ligament slits [7]. These findings suggest that the ITP block not only as "paravertebral-by-proxy" but, more importantly, as a "thoracic paraspinal nerve block" [8].

Recent clinical evidence supports ITP block efficacy for surgical anesthesia in procedures, such as open gastrectomy [9] and awake mastectomy [10], with demonstrated utility in postoperative analgesia following video-assisted thoracoscopic surgery [11] and major breast cancer operations [12]. LA administered via ITP block can spread into the paravertebral space, block sympathetic chain, and provide visceral analgesia [7, 9, 10]. However, the exact mechanisms and distribution patterns in living humans remain unclear.

We believe that further investigations in real patients are warranted. The aim of this imaging study was to compare the distribution of LA at the same concentration but at different volumes in ITP blocks using CT in living humans. To elucidate the distribution pattern, potential diffusion pathways, correlations between distribution regions and influences of other factors should be explored.

Methods

Study design and aims

This study is a prospective, single-center, double-blind randomized controlled imaging study. This study aims to characterize the distribution pattern of local anesthetics following ITP block, with an exploratory analysis of factors influencing this distribution. The primary focus is on observing the anesthetic spread.

Patient recruitment and group allocation

All patients were informed about the potential risks and benefits of the ITP block before enrollment. After obtaining informed consent, a total of 45 patients were enrolled and randomized into three groups at a 1:1:1 ratio. Different volumes of LA containing radiopaque contrast agent were administered separately to each group as follows: Group A received 0.3 ml/kg of 0.375% ropivacaine with 0.03 ml/kg of radiopaque contrast agent (OMNIPAQUE 300: 647 mg/ml of iohexol, equivalent to 300 mg of iodine/ml, GE Healthcare), Group B received 0.4 ml/kg of 0.375% ropivacaine with 0.04 ml/kg of OMNIPAQUE 300, and Group C received 0.5 ml/kg of 0.375% ropivacaine with 0.05 ml/kg of OMNIPAQUE 300. We enrolled patients classified as American Society of Anesthesiologists (ASA) physical status I or II, aged 18–75 years, scheduled for CT-guided percutaneous localization or microwave ablation of pulmonary nodules, and with a body mass index (BMI) of 18.5–28 kg/m^2. We excluded patients who refused to participate in the study, had severe renal dysfunction or liver dysfunction, severe cardiovascular or pulmonary diseases, were contraindicated for nerve block, had documented allergies to LA drugs or contrast agents, or had abnormal anatomy.

Randomization and blinding

The randomization process was performed by a statistician who was not involved in the study. Using the Statistical Package for the Social Sciences (SPSS) for block randomization, the block size was 9, generating 5 sets of random numbers in order of size. The top 3 were assigned to group A, the middle 3 were assigned to group B, and the last 3 were assigned to group C. The randomization results were placed sequentially in opaque envelopes and opened only by an experienced anesthetist who did not participate in this trial before the start of the nerve block. Except for the anesthesiologist and assistant responsible for administering the nerve block, the other anesthesiologists in the study remained blinded to group allocation. Post-block assessments were conducted by another trained anesthetist. Unblinding was implemented in the event of a serious adverse event.

Block techniques and surgical procedure

In the CT room, after standard ASA monitoring and intravenous access was established, the patients remained in a lateral position with the surgical site facing upward. Before intervention, we conducted a routine ultrasound examination on each patient to identify the target location of the block and whether the anatomy was normal. If the results were normal, intervention was implemented.

A 2–5 MHz curvilinear transducer (Mindray TE7; Bio-Medical Electronics, Shenzhen, China) was placed approximately 3 cm lateral to the lumbar spinous process in the sagittal plane and then moved slightly cephalad while also shifting laterally in parallel to identify the 12th rib. The transducer was gradually moved cephalad until the T4 or T5 vertebral body was confirmed. The target location was confirmed and then marked and sterilized. Scanning was repeated to identify the superior costotransverse ligament and pleura, and then local anesthesia was induced with 5 ml of 1% lidocaine. Using an out-of-plane technique, a 22–gauge 90–mm nerve block needle (AN–S1, Jiangsu Huaxing Medical Device Industrial Co., Ltd., China) was inserted from posterolateral to anteromedial above the transducer probe [13]. Advanced about 1 cm, inject a squirt of saline, and observed the ultrasound image of tissue expansion to confirm the needle tip position. Then advanced more slowly and repeat the injection of small amounts of saline until the needle tip reached the retro-superior costotransverse ligament space, predetermined drugs were injected (see Additional video file 1 and figure file 3, 4). All nerve blocks were performed by one experienced anesthesiologist (more than 200 ITP block or PV block peer year).

After the block was completed, the CT-guided percutaneous localization pulmonary nodules were performed immediately. First, the patient was promptly repositioned according to surgical needs, and the first CT-scan was performed. The thickness of image slices was set to 2.5 mm, covers the entire chest area, to determine the surface location of pulmonary nodules, puncture angle and distance. Second, nodule localization needle was insert based the result of CT-scan, following the second CT-scan was performed. Third, the angle and distance of insertion were reconfirmed, nodule localization needle was advanced into the lung parenchyma to reach the nodule and release its anchoring hooks. Finally, a third CT-scan was performed to confirm the location of the anchoring hooks and assess for complications such as bleeding or pneumothorax [14]. The ITP block was a part of the surgical anesthesia plan, all patients were transferred to the operating room for video-assisted thoracoscopic lung wedge resection after localization.

Safety consideration

The safety of the subjects was strictly considered throughout the study. All nerve blocks were performed by an experienced anesthesiologist and the whole operation was completed under the standard ASA monitors. An intravenous access was established and relevant emergency medicines were prepared. Any adverse events and complications were recorded and managed according to clinical guidelines. In the event of local anesthetic systemic toxicity, resuscitation equipment and lipid emulsion therapy were readily available. Pneumothorax, if necessary, closed chest drainage. Anaphylaxis was treated with epinephrine, airway management, and supportive care as required. Any study-related complications were promptly reported to the Clinical Research Ethics Committee, which was responsible for safety monitoring and ensuring appropriate treatment throughout the process.

Outcomes and assessments

The primary outcome was the distribution pattern of LA in nine predefined anatomical areas, including the mediastinal compartments (consisting of the prevascular compartment, visceral compartment, and paravertebral compartment) [15], retro-superior costotransverse ligament space [16], erector spinae fascia plane, intercostal space, sympathetic ganglion, costotransverse space [16], intervertebral foramen, lateral recess [17] and epidural space (Table 1). The secondary outcomes were as follows: (1) the maximum visual analogue scale (VAS) score during surgery and the VAS score after surgery; (2) dermatomal distribution of sensory loss; (3) adverse effects of the block; and (4) time required for the block.

The results of CT, multiplanar reconstruction, and three-dimensional image reconstruction were assessed together by a radiologist and an anesthesiologist who were blinded to the randomization allocation. After the last CT scan was completed, the skin on both sides was subjected to a cold sensation test. These tests were performed from the T1-T12 levels along the midclavicular line, midaxillary line and scapular line. The most severe pain during the surgery and the pain after the surgery were tested using a 100-mm VAS scale (where 0 = no pain and 100 = severe pain) after surgery. Nerve block-related adverse events and the time points of each CT scan were obtained from the electronic medical record system at our institution.

Statistical analysis

Owing to the exploratory nature of this study, conventional methods for calculating sample size were deemed difficult. Drawing upon insights from previous imaging studies, we included 45 patients in an exploratory study [18].

Unsatisfactory ITP block was defined as being similar to paravertebral (PV) block or ESP block, as determined by the radiologist and anesthesiologist reviewing the

Table 1 Nine predefined anatomical areas of interest

Area of interest	Definition
Mediastinal compartments	Consisting of the prevascular compartment, visceral compartment and paravertebral compartment
Retro-superior costotransverse ligament space	The space between the superior costotransverse ligament and erector spinae fascia plane
Erector spinae fascia plane	The fascial plane between the transversus process and erector spinae muscles
Intercostal space	The space between the intercostal muscles or the extension of the paravertebral space outward toward the region of the ribs
Sympathetic ganglion	The anterolateral region of the vertebral body
Costotransverse space	The space between the transversus processes and the ribs
Lateral recess	The space located on each side of the vertebral canal within the spinal column
Intervertebral foramen	The notches of adjacent vertebral arch
Epidural space	The space between the dura mater and the vertebrae

images. Unsatisfactory nerve blocks may be attributed to the technique itself, so we employed both intention-to-treat (ITT) and per-protocol (PP) analyses to assess whether the outcomes were influenced by the failure rate of the ITP block technique. Quantitative variables are expressed as medians (IQRs) or means (SDs), depending on normality, as assessed via Shapiro–Wilk tests. Qualitative variables are represented by frequencies (percentages).

For the primary outcome, descriptive statistics were used to present the findings, and differences in distribution patterns between the groups were tested using the Kruskal–Wallis test for quantitative variables and Fisher's exact test for qualitative variables. For secondary outcomes, we used ANOVA or the Kruskal–Wallis test for quantitative variables and Fisher's exact test for qualitative variables. We also categorized BMI into overweight (24–28 kg/m^{-2}) and normal weight (18.5–24 kg/m^{-2}) groups to evaluate its impact on the distribution pattern.

Exploratory statistical analyses were conducted to assess the correlation between distribution regions and the factors (e.g., patient positioning, drug volumes, BMI category) influencing the distribution pattern. Permutational multivariate analysis of variance (PERMANOVA) was performed using vegan, an R package, to assess the effects of groups, positions and BMI category on the overall distribution pattern of LA [19–21]. Multivariate linear regression models were used to analyze the effects of drug volume, patient position and BMI category on the distribution of LA in predefined anatomical areas. The Spearman rank correlation coefficient describes the associations between the primary outcomes. The Bonferroni correction was applied to reduce potential inflation of type I errors caused by multiple comparisons. Two-sided P values less than 0.05 indicated statistical significance. We used SPSS version 26.0 (IBM SPSS Inc., Chicago, IL, USA) and statistical R packages (version 4.4.1, Vienna, Austria) for analyses and data visualization [22, 23].

Results

A total of 45 subjects completed the study. Two subjects experienced unsatisfactory ITP blocks (one in Group B and another in Group C), and we included them in the ITT analysis but not in the PP analysis.

Baseline, surgical, and regional anesthesia characteristics

Figure 1 presents the CONSORT flow diagram, and Table 2 presents the detailed patient and surgical characteristics. The three-dimensional reconstructed images of the most standard diffusion model for the ITP block in our study are shown in Additional figure file 1.

Primary outcome

After ITP block, most contrast-containing LAs can spread to the paravertebral compartment, visceral compartment, intercostal space, erector spinae fascia plane and sympathetic ganglion (Table 3). A smaller portion spread to the prevascular compartment and epidural space, with almost no LA observed in the costotransverse space (Table 3).

Secondary outcomes

There were no significant differences in the maximum intraoperative pain scores among Group A, Group B, and Group C (mean [SD]: 43.8 [10.7] vs. 36.5 [11.5] vs. 35.9 [11.0]; $P=0.107$). Similarly, there were no significant differences in postoperative pain scores among the groups (mean [SD]: 22.6 [9.2] vs. 17.8 [8.1] vs. 17.9 [9.0]; $P=0.241$). The duration of the block procedure was similar across all three groups (median [IQR]: 4 [4, 5] vs. 4 [3, 5] vs. 3 [3, 4] minutes; $P=0.156$). Additionally, no block-related complications were noted in any of the groups (n [%]: 0 [0] vs. 0 [0] vs. 0 [0]; $P=1.0$). There were no significant differences in the dermatomal distribution of sensory blockade at the midclavicular line (mean [SD]: 3.5 [2.1] vs. 4.5 [2.7] vs. 4.0 [1.4]; $P=0.389$), midaxillary line (mean [SD]: 3.4 [2.0] vs. 4.5 [2.5] vs. 4.1 [1.4]; $P=0.302$),

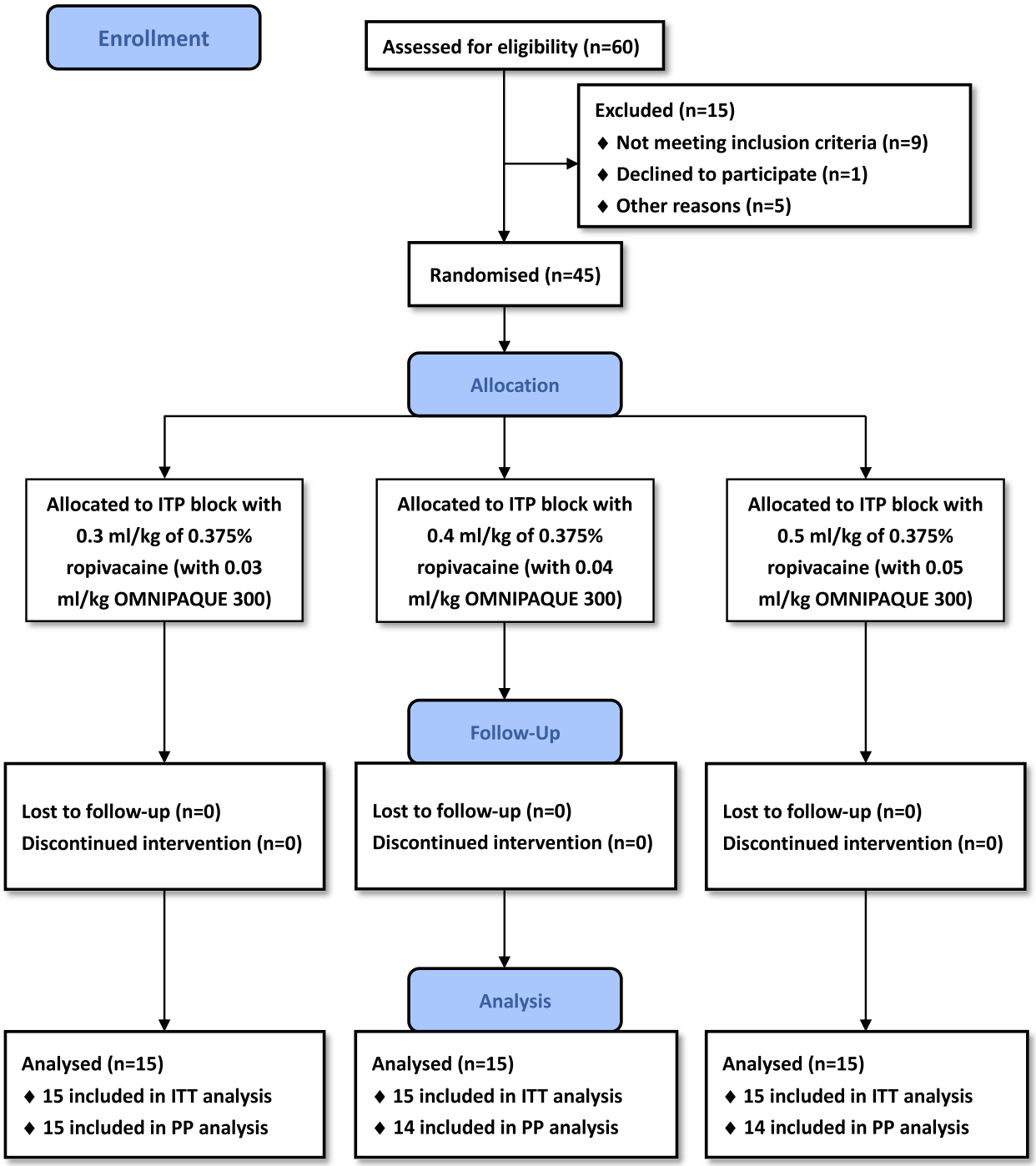

Fig. 1 CONSORT flow diagram. ITP, Intertransverse process; ITT, intention to treat; PP, per protocol

or scapular line (mean [SD]: 5.6 [1.5] vs. 7.0 [1.6] vs. 6.2 [1.4]; $P=0.052$). However, the participants experienced more widespread sensory loss in the posterior chest wall (see Additional figure file 2 and table file 1).

Exploratory statistical analyses

PERMANOVA using Bray–Curtis distance revealed that the distribution pattern of LA was significantly affected by patient positioning (ITT: $R^2=0.07$, F. Model = 3.43,

Table 2 Patient and surgical characteristics

	Group A $n=15$	Group B $n=15$	Group C $n=15$
Patient characteristics			
Age (years)	60 (10)	56 (9)	59 (9)
Sex (n, %)			
Male	8 (53.3)	7 (46.7)	8 (53.3)
Female	7 (46.7)	8 (53.3)	7 (46.7)
total weight (kg)	59.3 (12.5)	63.1 (8.6)	61.9 (10.4)
ideal weight (kg)	60.5 (10.3)	58.5 (9.4)	61.0 (8.6)
BMI ($kg{\cdot}m^{-2}$)	22.2 (3.5)	24.2 (2.5)	23.4 (3.0)
ASA status (n, %)			
I	0 (0)	0 (0)	0 (0)
II	15 (100)	15 (100)	15 (100)
Types of surgery (n, %)			
percutaneous localization of pulmonary nodules	15 (100)	15 (100)	15 (100)
microwave ablation of pulmonary nodules	0 (0)	0 (0)	0 (0)
Diagnosis (n, %)			
Left lung nodule	3 (20)	4 (26.7)	5 (33.3)
Right lung nodule	10 (66.7)	9 (60)	10 (66.7)
Bilateral lung nodules	2 (13.3)	2 (13.3)	0 (0)
Smoking history (n, %)	4 (26.7)	4 (26.7)	3 (20)
Surgical and regional anesthesia characteristics			
Radiation dose (mSv)	19.6 (18.2–29.2)	21.6 (17.3–25.1)	17.6 (16.7–20.0)
Surgical position (n, %)			
Supine	5 (33.3)	4 (26.7)	1 (6.7)
Lateral	5 (33.3)	7 (46.7)	6 (40)
Prone	5 (33.3)	4 (26.7)	8 (53.3)
Distance from skin to paravertebral space (cm)	4 (3.25–4.25)	3.5 (3.5–4.0)	4 (3.5–4.0)
Puncture time[a] (min)	4 (3–8)	4 (3–10)	3 (2–5)
Block-to-CT time[b] (second)	114 (24)	125 (31)	126 (24)

Data are expressed as means and SDs, frequencies and percentages, or medians and IQRs as appropriate

BMI body mass index, *ASA* American Society of Anesthesiologists, *CT* computed tomography

[a] Time from the start of the puncture to the withdrawal of the puncture needle

[b] Time from withdrawal of the nerve block needle to the first CT scan

$P=0.04$; PP: $R^2=0.08$, F. Model = 3.67, $P=0.03$), while anesthetic volume (ITT: $R^2=0.03$, F. Model = 1.60, $P=0.20$; PP: $R^2=0.02$, F. Model = 1.01, $P=0.35$) and BMI category (ITT: $R^2=0.03$, F. Model = 1.36, $P=0.26$; PP: $R^2=0.01$, F. Model = 0.60, $P=0.62$) showed no significant effect. The ITT and PP analyses revealed consistent results.

Multiple linear regression analysis revealed a significant effect of independent variables (drug volume, BMI category and patient position) on anesthetic distribution in the prevascular compartment ($R^2=0.37$, F = 4.50, $P=0.002$). The prone position had a significant positive effect (B = 2.45, 95% CI (0.96, 3.95), $P=0.002$). The results of multiple linear regression analysis for other regions were not statistically significant after applying the Bonferroni correction ($P>0.0045$, Fig. 2). There were correlations in the distribution of LA between predefined areas (Fig. 2).

Discussion

This study investigated the distribution patterns of three different volumes but the same concentration of LAs for ITP block in humans. In this study, we observed substantial LA spread to the paravertebral compartment, intercostal space, and erector spinae fascia plane after ITP block, which is consistent with findings from previous cadaveric studies [6, 7, 24]. Both the VAS pain scores and the range of dermatomal sensory loss were similar across the groups, and no block-related complications were observed. Unlike cadaver studies, CT imaging studies can reveal continuous changes in subtle areas, allowing better

Table 3 Descriptive statistics of the primary outcomes

	Group A $n=15$	Group B $n=15$	Group C $n=15$	Total $n=45$	*P* value [*, †, ‡]
The overall distribution (n, %)					
Mediastinal compartments					
Prevascular compartment	2 (13.3)	3 (20)	6 (40)	11 (24.4)	0.31
Visceral Compartment	10 (66.7)	10 (66.7)	15 (100)	35 (77.8)	0.03
Paravertebral compartment	14 (93.3)	13 (86.7)	15 (100)	42 (93.3)	0.76
Retro-superior costotransverse ligament space	15 (100)	14 (93.3)	15 (100)	44 (97.8)	0.99
Erector spinae fascia plane	15 (100)	15 (100)	14 (93.3)	44 (97.8)	0.99
Intercostal space	15 (100)	14 (93.3)	15 (100)	44 (97.8)	0.99
Sympathetic ganglion	13 (86.7)	12 (80)	15 (100)	40 (88.9)	0.34
Costotransverse space	0 (0)	1 (6.7)	0 (0)	1 (2.2)	0.99
Lateral recess	1 (6.7)	3 (20)	2 (13.3)	6 (13.3)	0.86
Intervertebral foramen	1 (6.7)	3 (20)	4 (26.7)	8 (17.8)	0.49
Epidural space	1 (6.7)	1 (6.7)	1 (6.7)	3 (6.7)	0.99
Vertebral levels at the sagittal distribution					
Mediastinal compartments					
Prevascular compartment	0 (0–0)	0 (0–0)	0 (0–3)	0 (0–1)	0.29
Visceral compartment	2 (0–5)	1 (0–3)	4 (2–9)	1 (2–5)	0.01
Paravertebral compartment	2 (1–4)	4 (1–8)	2 (2–6)	2 (2–6)	0.65
Retro-superior costotransverse ligament space	1 (1–1)	1 (1–1)	1 (1–2)	1 (1–1)	0.30
Erector spinae fascia plane	5 (4–6)	6 (5–7)	5 (5–6)	5 (4.5–6)	0.08
Intercostal space	3 (1–4)	3 (1–5)	3 (3–4)	3 (1–4.5)	0.69
Sympathetic ganglion	2 (1–4)	3 (1–7)	2 (2–6)	2 (1.5–6)	0.61
Costotransverse space	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0.37
Lateral recess	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0.59
Intervertebral foramen	0 (0–0)	0 (0–0)	0 (0–1)	0 (0–0)	0.35
Epidural space	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	1.00

Data are expressed as medians and IQRs, frequencies and percentages, as appropriate

[*]: *P* values compared among the three groups

[†]: *P* values were calculated using the Kruskal–Wallis test or Fisher's exact test as appropriate

[‡]: $P<0.0045$ indicates statistical significance among the three groups after Bonferroni correction

assessment of the distribution pattern of the LA. After ITP block, the LA readily spreads to the paravertebral compartment, covering a median of 2 (2–6) vertebral levels (Table 3). The dermatomal sensory loss in our study, averaging 3.5–4.5 levels in the anterior hemithorax, was similar to the 4.36 levels reported by Nielsen et al. [25]. At the block site, we observed the LA distribution in the retro-superior costotransverse ligament space, but this distribution was typically limited to one vertebral level and rarely extended to the costotransverse space. This finding contrasts with the hypothesis of Cho et al. [7]. We speculate that differences in tissue density and pressure gradient between living human subjects and cadavers may account for these discrepancies in LA distribution. We propose that the intersegmental spread of the ITP block occurs by initially reaching the paravertebral compartment, followed by cephalocaudal spread.

Karmakar et al. [8] performed a single-level ITP block using 10.5 mL of 0.5% bupivacaine at the medial retro-superior costotransverse ligament space (T4-T5), reporting 100% ($n=10$) epidural and intervertebral foramen spread. In contrast, our study utilized a more lateral injection site (Additional figure file 4). We observed intervertebral foramen spread in 17.8% ($n=8$) and epidural spread in 6.7% ($n=3$) of participants (Table 3, Additional figure file 5). Despite using a lower anesthetic volume, Karmakar et al. [8] observed comparable paravertebral compartment (2 [1–2.2] levels) spread but greater distribution to the sympathetic ganglia (4 [3–6.2] levels), epidural space (6.5 [4–9.2] levels), and intervertebral foramen (5.5 [3–6.7] levels). The range of intercostal space spread in our study was greater than Karmakar et al. [8] (3 [1–4.5] vs 2 [1–3]). These differences may be attributed to needle positioning. A medial injection site is closer to the CTF, where

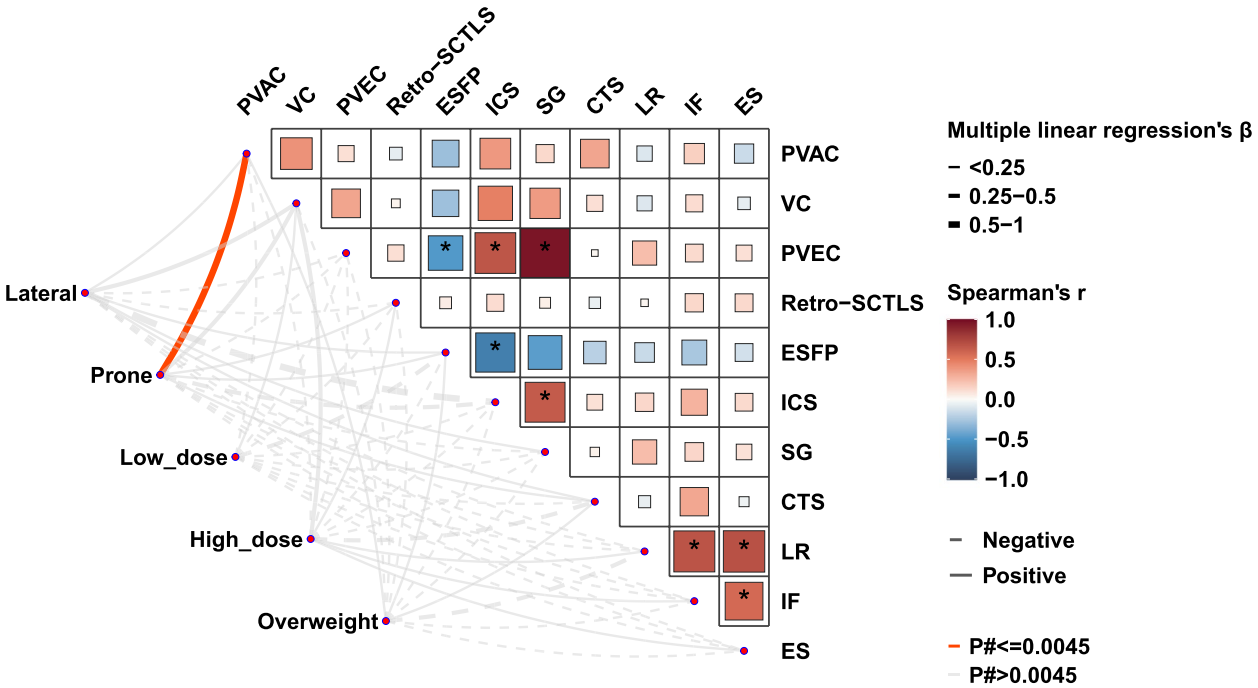

Fig. 2 Pairwise comparisons of predefined regions are shown with a color gradient denoting Spearman's correlation coefficients. Multiple linear regression analyses were conducted using the dummy variable (independent variable) and predefined regions (dependent variables). The results are depicted through connecting lines, where solid lines indicate positive correlations and dotted lines indicate negative correlations. Edge width indicates the magnitude of the effect between the independent variable and the dependent variable (i.e., multiple linear regression's β), and edge color indicates statistical significance. * Denotes a significant correlation between two regions even after Bonferroni correction; P# indicates the P value after Bonferroni correction. PVAC, prevascular compartment; VC, visceral compartment; PVEC, paravertebral compartment; Retro-SCTLS, retro-superior costotransverse ligament space; ESFP, erector spinae fascia plane; ICS, intercostal space; SG, sympathetic ganglion; CTS, costotransverse space; LR, lateral recess; IF, intervertebral foramen; ES, epidural space

lower resistance facilitates anterior and medial spread [8]. Although paravertebral compartment spread was similar between these two studies, our total drug volume exceeded 10.5 mL even at 0.3 ml/kg.

Additionally, Karmakar et al. [8] employed a uniform patient position and there were three different positions in our study. We found significant prevascular and visceral compartment spread, which may have influenced paravertebral distribution. These methodological differences make it difficult to directly compare our results with those of Karmakar et al. [8]. But we can still observe some trends. Medial injections favored anterior and medial spread [8], whereas lateral injections resulted in more posterior and lateral distribution. We did not observe any changes in the patients' blood pressure or heart rate, which is consistent with previous reported [26]. This may be because contralateral spread is more limited after ITP block than after epidural anesthesia, and the dose involved is only the tip of the iceberg of the total drugs used.

There were correlations in the distribution of LA between predefined areas. The distribution of LA to the paravertebral compartment was negatively correlated with the erector spinae fascia plane, and similar conclusions were reached in a previous cadaver study [2, 7]. There were significant positive correlations among the paravertebral compartment, sympathetic ganglion, and intercostal space, as well as among the intervertebral foramen, lateral recess, and epidural space, likely due to their close anatomical proximity. The participants showed more widespread sensory loss in the posterior chest wall (see Additional figure file 2 and table file 1), indicating that ITP block may have greater posterior than anterior spread, which is consistent with the findings of the study by Costache et al. [2]. In general, the distribution pattern of the LA after an ITP block is predictable and involves both anterior and posterior spread.

Therefore, we considered the nine predefined areas as a whole and used PERMANOVA to analyze differences in the overall distribution pattern [20, 21]. The results revealed that the overall distribution pattern of LA was significantly affected by patient position (R^2=0.07, F. Model=3.43, P=0.04) rather than LA volume (R^2=0.03, F. Model=1.60, P=0.20) and BMI category (R^2=0.03, F. Model=1.36, P=0.26). The results of multiple linear regression analysis revealed that, compared with supine positioning, prone

positioning led to the accumulation of LA between the parietal pleura and the anterior chest wall and spread to the prevascular compartment. This phenomenon occurs immediately with changes in patient positioning, and the LA tends to concentrate in areas with the lowest gravitational potential in the vertical direction (Fig. 3). Fuhrmann et al. [27] reported that mediastinal fluid can extend from the visceral compartment to the paravertebral compartment. Therefore, we hypothesize that because the parietal pleura and chest wall exhibit significant fluidity, anesthetics can easily flow between the prevascular compartment, paravertebral compartment, and visceral compartment. The "fluidity" may explain the position-dependent distribution pattern observed in our study.

The endothoracic fascia divides the paravertebral area into the extrapleural paravertebral compartment and the subendothoracic paravertebral compartment [28, 29]. Previous studies have suggested that injections into the extrapleural paravertebral compartment may result in wider diffusion and more ideal 'cloud-like' spread [28, 29]. Injections into the subendothoracic paravertebral compartment may lead to contralateral paravertebral spread [28, 29]. In our study, the injection target was far from the extrapleural paravertebral compartment, making it impossible to pierce the endothoracic fascia [16]. However, we observed visceral compartment diffusion and did not find contralateral paravertebral or contralateral prevertebral spread. This phenomenon may indicate that LA can spread to the endothoracic fascia.

Our study has several limitations: (1) Because our study was exploratory in nature, no sample size calculations were conducted. The statistical power may be insufficient

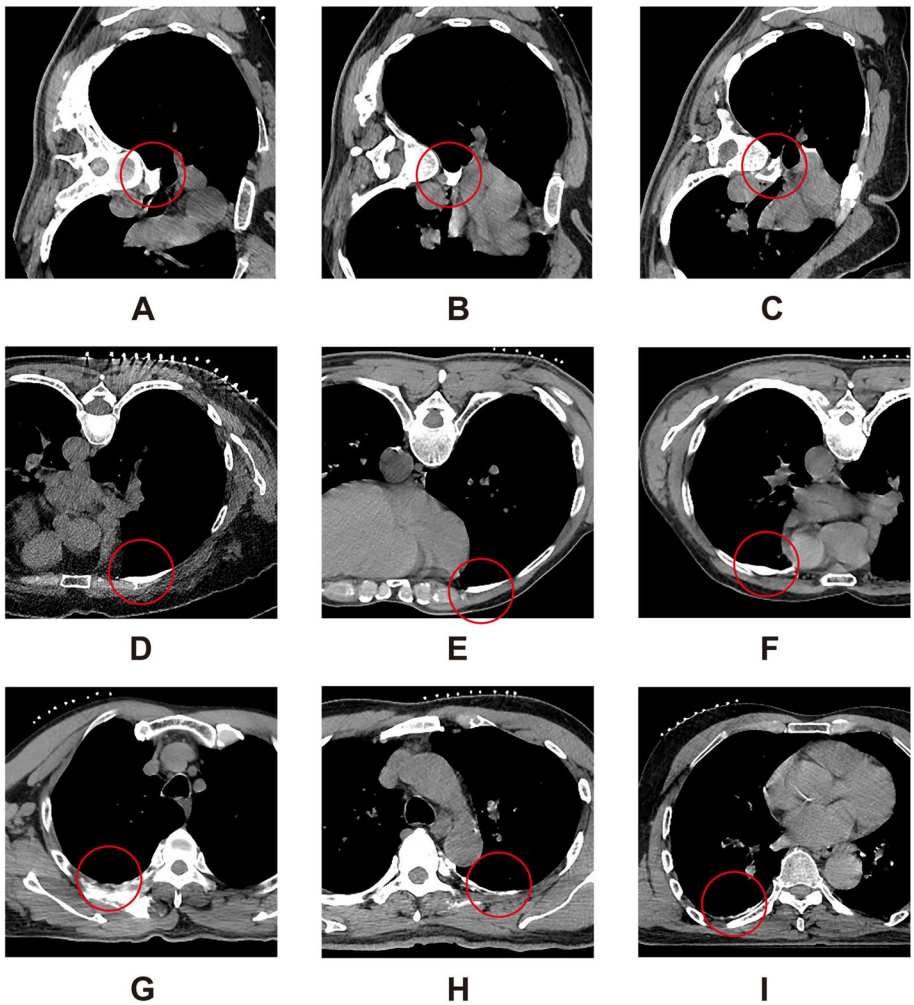

Fig. 3 CT images showing that local anesthetics are concentrated in areas with the lowest gravitational potential. The red circles indicate the local anesthetics. **A**, **B**, **C** show predominant spread to the visceral compartment in the lateral position. **D**, **E**, **F** show predominant spread to the area between the parietal pleura and the anterior chest wall or the prevascular compartment in the prone position. **G**, **H**, **I** show predominant spread to the area between the parietal pleura and the posterior chest wall or the intercostal space in the supine position

due to the small sample size. Although we used conservative statistical methods, larger-scale studies are needed in the future. (2) We only observed the distribution of the LA in the early period due to the brief duration of the puncture and the rapid absorption of the contrast agent. (3) The ITP block technique we used differs from that used in previous studies, which may have resulted in inconsistencies in needle tip positioning. Further studies are necessary to explore whether different needle positions in ITP block affect distribution patterns.

Conclusion

In conclusion, after ITP block, the LA predominantly spreads to the paravertebral compartment, visceral compartment, intercostal space, sympathetic ganglion, and erector spinae fascia plane. Minimal spread was observed in the prevascular compartment and epidural space. Increasing the volume of the LA to 0.3–0.5 ml/kg did not result in a wider distribution range; instead, the overall distribution pattern was primarily influenced by patient positioning. LA spreads more to the prevascular compartment in the prone position, indicating that the drug distribution is affected by gravity in the vertical direction. Given the variability in paravertebral spread, caution is warranted when increasing the LA dose. Future studies should further investigate the impact of body positioning on distribution patterns to optimize clinical application of ITP block.

Abbreviations

ITP	Intertransverse process
MTP	Midpoint transverse process to pleura
STIL	Sub-transverse process interligamentary plane
CTF	Costotransverse foramen
MIC	Multiple injection costotransverse
LA	Local anesthetic
VAS	Visual analogue scale
CT	Computed tomography
ESP	Erector spinae plane
ASA	American Society of Anesthesiologists
BMI	Body mass index
SPSS	Statistical Package for the Social Sciences
ITT	Intention-to-treat
PP	Per-protocol
IQR	Interquartile range
SD	Standard deviation
ANOVA	Analysis of variance
PERMANOVA	Permutational multivariate analysis of variance
CONSORT	Consolidated standards of reporting trials

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12871-025-03017-x.

Additional file 1: figure S1. Three-dimensional reconstructed images showing the distribution pattern after ITP block. (A) (C) Distribution pattern in the erector spinae plane; (B) intercostal and paravertebral spaces; (D) and intercostal, paravertebral, and visceral compartments. ITP, intertransverse process

Additional file 2: figure S2. Dermatomal spread in different thoracic reference lines. The dermatomal spread of the blockade was assessed via cold tests after the last CT scan was completed. The range is shown as a bar, indicating the extent of the blockade from the lowermost to the uppermost dermatome. Each bar represents the dermatomal spread of the blockade in each subject. Different colors represent different thoracic reference lines. Three patients in Group A had clearly decreased sensation at only one vertebral level. One subject in Group B had no clearly decreased sensation in the midclavicular or midaxillary lines, and none of the subjects had decreased sensation in the contralateral hemithorax. MACL, midclavicular line; MAL, midaxillary; SCL, scapular line

Additional file 3: figure S3. Ultrasound images showing the steps of our ITP block. (A) Step 1: identification of the target areas. (B) Step 2: Advancement of the needle by approximately 1 cm, followed by a test injection of saline. (C) Step 3: Advanced needle slowly and repeat the injection. (D) Steps 4: Needle reaching the retro-superior costotransverse ligament space and injected predetermined drugs. (E) Transversal ultrasound image at T4 at the level of the transverse process in the same patient after the ITP block was completed. (F) Transversal ultrasound image at T4 at the level of the inferior articular process in the same patient after the ITP block was completed. Black dotted lines indicate the pleura, red dotted lines indicate the superior costotransverse ligament. Red asterisk marks the needle tip. Green asterisk marks the lateral retro-superior costotransverse ligament space and purple asterisk marks the medial retro-superior costotransverse ligament space

Additional file 4: figure S4. Demonstration and CT images of our intertransverse process block technique. (A) Orientation of the ultrasound transducer and needle positioning. (B) Representative CT image showing the needle position and the spread of the local anesthetic. Red arrow indicates the insertion site, and bule arrow indicates intercostal space spread, green arrow indicates paravertebral compartment spread, yellow arrow indicates sympathetic ganglia spread, pink arrow indicates visceral compartment spread and purple arrow indicates the length of superior costotransverse ligament. Black dotted line outlines the superior costotransverse ligament, and red dotted line marks the erector spinae fascia plane, red oval circle highlights the space spread between parietal pleura and posterior chest wall. Blue asterisk denotes the lateral retro-superior costotransverse ligament space and red asterisk denotes the medial retro-superior costotransverse ligament space

Additional file 5: figure S5. CT images showing epidural space spread after the ITP block. Red arrows indicate ipsilateral spread, and green arrows indicate contralateral spread. A-F, G-J, and K-N represent three different patients. D, H, and L indicate the vertebral levels of the respective injections. A, B, G, and K show only contralateral spread, with no ipsilateral spread. ITP, intertransverse process

Additional file 6: Table S1. Intra-group comparison of dermatomal distribution across different regions

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Authors' contributions

CWW and PZ contributed to writing the original draft, reviewing and editing, conceptualization, visualization, methodology, project administration, formal analysis, and investigation. ZXZ and MYS participated in investigation, writing review and editing, data curation, and resources. QGY was responsible for data curation, formal analysis, investigation, visualization, and software. LFZ handled conceptualization, writing review and editing, visualization, methodology, supervision, validation, resources, project administration, and formal analysis.

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Data availability

All data will be uploaded to the clinical trial management public platform (http://www.medresman.org.cn/pub/en/proj/listbyproj.aspx?proj=11,224).

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines. Ethical approval was obtained from the Research Ethics Committee of the first affiliated of Gannan Medical University (reference number: llsc-2024106) on March 27, 2024. The trial was registered online on 3 April 2024 in the Chinese Clinical Trial Registry (ChiCTR2400082665, https://www.chictr.org.cn/showproj.html?proj=225158), and the first patient was enrolled on April 3, 2024. Written informed consent was obtained from all participants in this study.

Consent for publication

Not applicable.

Competing of interests

The authors declare that they have no competing interests.

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References

1. El-Boghdadly K, Wolmarans M, Stengel AD, Albrecht E, Chin KJ, Elsharkawy H, et al. Standardizing nomenclature in regional anesthesia: an ASRA-ESRA Delphi consensus study of abdominal wall, paraspinal, and chest wall blocks. Reg Anesth Pain Med. 2021;46(7):571–80.
2. Costache I, de Neumann L, Ramnanan CJ, Goodwin SL, Pawa A, Abdallah FW, et al. The mid-point transverse process to pleura (MTP) block: a new end-point for thoracic paravertebral block. Anaesthesia. 2017;72(10):1230–6.
3. Shibata Y, Kampitak W, Tansatit T. The Novel Costotransverse Foramen Block Technique: Distribution Characteristics of Injectate Compared with Erector Spinae Plane Block. Pain Physician. 2020;23(3):E305–14.
4. Kilicaslan A, Sarkilar G, Altınok T, Tulgar S. A novel ultrasound-guided technique in peri-paravertebral area: Subtransverse process interligamentary (STIL) plane block: The game has not ended yet. J Clin Anesth. 2020;60:76–7.
5. Nielsen MV, Moriggl B, Hoermann R, Nielsen TD, Bendtsen TF, Børglum J. Are single-injection erector spinae plane block and multiple-injection costotransverse block equivalent to thoracic paravertebral block? Acta Anaesthesiol Scand. 2019;63(9):1231–8.
6. Varela V, Ruíz C, Montecinos S, Prats-Galino A, Sala-Blanch X. Spread of local anesthetic injected in the paravertebral space, intertransverse processes space, and erector spinae plane: a cadaveric model. Reg Anesth Pain Med. 2024;49(3):228–32.
7. Cho T-H, Kwon H-J, O J, Cho J, Kim SH, Yang H-M. The pathway of injectate spread during thoracic intertransverse process (ITP) block: Micro-computed tomography findings and anatomical evaluations. J Clin Anesth. 2022;77:110646.
8. Pangthipampai P, Siriwanarangsun P, Pakpirom J, Sivakumar RK, Karmakar MK. Intertransverse process block (ITPB) at the retro-superior costotransverse ligament (retro-SCTL) space: Evaluation of local anesthetic spread using MRI and sensory blockade in healthy volunteers. J Clin Anesth. 2025;101: 111718.
9. Marrone F, Failli S, Fabbri F, Paventi S, Lepre L, Virno V, et al. Erector Spinae Plane Block Together With Inter-Transverse Process Block for Open Gastrectomy: Case Report. A A Pract. 2025;19(2): e01918.
10. Marrone F, Fusco PF, Paventi S, Tomei M, Failli S, Fabbri F, et al. Combined thoracic erector spinae plane and inter-transverse plane blocks for awake breast surgery. Anaesth Rep. 2024;12(1): e12294.
11. Oh C, Chong Y, Kang MW, Bae J, Lee S, Jo Y, et al. Comparison between costotransverse foramen block and thoracic paravertebral block for VATS pulmonary resection: A randomized noninferiority trial. J Clin Anesth. 2023;88: 111127.
12. Zhang H, Qu Z, Miao Y, Zhang Y, Qian L, Hua B, et al. Comparison between ultrasound-guided multi-injection intertransverse process and thoracic paravertebral blocks for major breast cancer surgery: a randomized non-inferiority trial. Reg Anesth Pain Med. 2023;48(4):161–6.
13. Krediet AC, Moayeri N, van Geffen GJ, Bruhn J, Renes S, Bigeleisen PE, et al. Different Approaches to Ultrasound-guided Thoracic Paravertebral Block: An Illustrated Review. Anesthesiology. 2015;123(2):459–74.
14. Klinkenberg TJ, Dinjens L, Wolf RFE, van der Wekken AJ, van de Wauwer C, de Bock GH, et al. CT-guided percutaneous hookwire localization increases the efficacy and safety of VATS for pulmonary nodules. J Surg Oncol. 2017;115(7):898–904.
15. Carter BW, Benveniste MF, Madan R, Godoy MC, de Groot PM, Truong MT, et al. ITMIG Classification of Mediastinal Compartments and Multidisciplinary Approach to Mediastinal Masses. Radiographics. 2017;37(2):413–36.
16. Cho T-H, Kim SH, O J, Kwon H-J, Kim KW, Yang H-M. Anatomy of the thoracic paravertebral space: 3D micro-CT findings and their clinical implications for nerve blockade. Reg Anesth Pain Med. 2021;46(8):699–703.
17. Katz JN, Zimmerman ZE, Mass H, Makhni MC. Diagnosis and Management of Lumbar Spinal Stenosis: A Review. JAMA. 2022;327(17):1688–99.
18. Balocco AL, López AM, Kesteloot C, Horn J-L, Brichant J-F, Vandepitte C, et al. Quadratus lumborum block: an imaging study of three approaches. Reg Anesth Pain Med. 2021;46(1):35–40.
19. Oksanen J, Simpson GL, Blanchet FG, Kindt R, Legendre P, Minchin PR, et al. vegan: Community Ecology Package. 2024.
20. Anderson MJ. A new method for non-parametric multivariate analysis of variance. Austral Ecol. 2001;26(1):32–46.
21. Anderson MJ. Permutational Multivariate Analysis of Variance (PERMANOVA). In: Balakrishnan TC, B. Everitt, W. Piegorsch, F. Ruggeri and J.L. Teugels, editor. Wiley StatsRef: Statistics Reference Online: Wiley; 2017. p. 1–15.
22. Huang H. linkET: Everything is Linkable. 2021.
23. Wickham H. ggplot2: Elegant Graphics for Data Analysis. 2016.
24. Kim JY, Lee U-Y, Kim D-H, Han DW, Kim SH, Cho YJ, et al. Comparison of injectate spread and nerve coverage between single-injection intertransverse process block and paravertebral block at the T2 level: a cadaveric study. Reg Anesth Pain Med. 2024;49(6):436–9.
25. Nielsen MV, Tanggaard K, Bojesen S, Birkebaek AF, Therkelsen AS, Sorensen H, et al. Efficacy of the intertransverse process block: single or multiple injection? A randomized, non-inferiority, blinded, cross-over trial in healthy volunteers. Reg Anesth Pain Med. 2023.
26. Karmakar MK, Sivakumar RK, Sheah K, Pangthipampai P, Lönnqvist PA. The Retro Superior Costotransverse Ligament Space as a New Target for Ultrasound-Guided Intertransverse Process Block: A Report of 2 Cases. A A Pract. 2022;16(7): e01610.
27. Fuhrmann C, Weissenborn M, Salman S. Mediastinal fluid as a predictor for esophageal perforation as the cause of pneumomediastinum. Emerg Radiol. 2021;28(2):233–8.
28. Karmakar MK, Chung DC. Variability of a thoracic paravertebral block. Are we ignoring the endothoracic fascia? Reg Anesth Pain Med. 2000;25(3):325–7.
29. Karmakar MK, Kwok WH, Kew J. Thoracic paravertebral block: radiological evidence of contralateral spread anterior to the vertebral bodies. Br J Anaesth. 2000;84(2):263–5.

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