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Clinical Investigation

REGIONAL ANAESTHESIA

Spread of local anaesthetic after erector spinae plane block: a randomised, three-dimensional reconstruction, imaging study

Tao Shan[1,†], Xiaodan Zhang[1,†], Zhenyu Zhao[2], Xiao Zhou[1], Hongguang Bao[1,*], Chuan Su[3,*], Qilian Tan[1], Liu Han[1] and Jun Yin[1]

[1]Department of Anaesthesiology, Perioperative and Pain Medicine, Nanjing First Hospital, Nanjing Medical University, Nanjing, China, [2]Department of Nuclear-Medicine, Nanjing First Hospital, Nanjing Medical University, Nanjing, China and [3]Center for Global Health, Department of Pathogen Biology and Immunology, Jiangsu Key Laboratory of Pathogen Biology, State Key Lab of Reproductive Medicine, Nanjing Medical University, Nanjing, China

*Corresponding authors. E-mails: hongguangbao@hotmail.com, chuansu@njmu.edu.cn
†These authors have contributed equally to this study and share first authorship.

Abstract

Background: Spread of local anaesthetic solution in the paravertebral space after erector spinae plane block (ESPB) is variable. We evaluated whether paravertebral spread of local anaesthetic is affected by patient position after ESPB.
Methods: We randomised 84 patients to receive ESPB at T_7 with a mixture of 0.375% ropivacaine and radiocontrast dye (30 ml). Participants were positioned supine, prone, or lateral for 30 min after ESPB before computed tomography scanning. The primary outcome was paravertebral space local anaesthetic spread, with secondary assessments of craniocaudal spread and distribution to neural foramina, and intercostal and epidural spaces. Loss of sensation to cold was recorded.
Results: Local anaesthetic–contrast mix reached the paravertebral space, intercostal space, and neural foramina in 96.5%, 94.2%, and 77.9% of individuals, respectively. Epidural space spread occurred in 20 cases. Prone positioning consistently allowed paravertebral and intercostal spread in all patients, with more thoracic level spread compared with supine positioning (5.0 [1.9] *vs* 3.1 [1.7], difference [95% confidence interval, CI]: 1.9 [0.8–3.0] levels, $P<0.001$ for paravertebral space spread; 2.8 [1.9] *vs* 1.4 [1.4], difference [95% CI] levels: 1.4 [0.4–2.5], $P=0.004$ for neural foramina spread; 4.3 [1.3] *vs* 3.2 [1.5], difference [95% CI] levels: 1.0 [0.1–1.9], $P=0.019$ for intercostal space spread). Local anaesthetic–contrast extended to the intercostal space further in the prone than in the lateral position group (4.3 [1.3] *vs* 2.6 [1.5] thoracic levels, difference [95% CI]: 1.7 [0.8–2.6], $P<0.001$). Sensory block in ventral dermatomes was variable in all participants.
Conclusions: Prone positioning after ESPB significantly enhanced local anaesthetic–contrast spread to the paravertebral space, intercostal space, and neural foramina, suggesting that gravity plays a substantial role in spread.
Clinical trial registration: Clinical Trials.gov (NCT06142630).

Keywords: computed tomography; erector spinae plane block; local anaesthetic spread; patient position; regional anaesthesia; three-dimensional imaging

Editor's key points

- Spread of local anaesthetic solution after erector spinae plane block (ESPB) is variable.
- The effect of patient position after ESPB on the paravertebral spread of a local anaesthetic–radiocontrast dye mixture was evaluated in patients undergoing thoracic image-guided needle localisation CT imaging.
- Injectate reached the paravertebral space and intercostal space in more than 90% of individuals, neural

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foramina in 78% of individuals, and epidural space in 24% of individuals.
- Nevertheless, sensory block of the abdominal and chest wall was highly variable.
- Prone positioning enhanced injectate spread to the paravertebral space, intercostal space, and neural foramen, consistent with a role for gravity in local anaesthetic spread.

Erector spinae plane block (ESPB)[1] is an interfascial block technique, with local anaesthetic injected between the erector spinae muscle and transverse process. The injected local anaesthetic can spread across the intertransverse connective tissue complex into the paravertebral space and then potentially into the epidural space anaesthetising the ventral branches of thoracic spinal nerves and the sympathetic nerve chain.[2–5] Nevertheless, anterior spread of local anaesthetic for ESPB in anatomical and clinical studies is variable.[6,7]

The ESPB is of interest because of its potential effects on the ventral branches of the spinal nerves. A study conducted on cadaveric specimens revealed that staining reached the paravertebral space in only one instance, affecting the ventral branches of the spinal nerves.[8] However, another cadaveric study found that the ventral branches were stainable, suggesting that dye could reach the paravertebral space, highlighting inconsistencies in spread.[9] Inconsistency of local anaesthetic spread to the paravertebral space was also seen in clinical imaging studies. Some studies have shown consistent spread of local anaesthetic into the paravertebral, intercostal, and even epidural spaces, offering positive evidence for the block of the ventral branches of the spinal nerves.[10,11] In contrast, other imaging studies showed limited extension to the paravertebral space.[12,13]

The clinical analgesic effects of ESPB are also debated.[14] Some studies have reported that ESPB does not reduce perioperative opioid consumption in cardiac surgery, casting doubt on its efficacy,[15,16] whereas other studies have shown that ESPB analgesic effects are comparable to, or even superior to, those of paravertebral block.[17,18] The presence of varying outcomes in these high-quality trials has sown seeds of doubt regarding the clinical efficacy of ESPB. Thus, increasing the stability of anterior spread of local anaesthetic and analgesic efficacy has become an important issue for ESPB. Various methods have been adopted to improve the reliability of ESPB, including alteration of the injection point to midway between transverse processes,[19] the costotransverse foramen[20] or midway between the tip of the transverse process, the lamina of the vertebra,[21] or a combination of ESPB with retrolaminar block,[22,23] but with varying degrees of success.

In thoracic surgery, ESPB is administered either before or after operation, with patients positioned laterally during surgery or supine after surgery. Studies[18,24,25] have reported that when patients were maintained laterally after ESPB, analgesic effects were comparable to those of paravertebral block or epidural analgesia. Meanwhile, performing the ESPB after operation with patients supine did not reduce opioid consumption.[15,16] The divergent outcomes of these studies led us to consider the role of patient positioning in the efficacy of ESPB. We speculated that the differences in spread exerted by gravity based on patient position in ESPB might be a contributing factor to observed variations in local anaesthetic spread and analgesic efficacy. We hypothesised that patients maintaining different positions after ESPB would influence local anaesthetic spread. This trial was performed to investigate whether paravertebral space spread of local anaesthetic was enhanced in patients maintaining prone or lateral positions after ESPB.

Methods

This was a single-centre, randomised, prospective trial conducted at Nanjing First Hospital. The trial was approved by the ethics committee of Nanjing First Hospital on September 15, 2023 (KY20230915-04) and prospectively registered at Clinical Trials.gov (NCT06142630, registration date: November 21, 2023) before patient enrolment. Written informed consent was obtained from all subjects before commencement of the trial.

Participants and randomisation

We recruited patients aged 18–80 yr and ASA physical status 1 or 2, receiving CT-guided percutaneous localisation of pulmonary nodules under local anaesthesia before surgery. Exclusion criteria were: (1) allergy to local anaesthetic, (2) history of opioid abuse, (3) infection at the puncture site, (4) peripheral neuropathy, (5) coagulation disorder or continuous use of anticoagulants before surgery, or (6) dementia, language barrier, or neuropsychiatric disorder.

We used SPSS 22.0 software (IBM, Armonk, NY, USA) to establish a 1:1:1 allocation ratio for our study participants. The allocations were securely sealed within sequentially numbered, opaque envelopes by a dedicated study coordinator. These envelopes were only opened immediately before the intervention. Two senior anaesthesiologists not involved in the trial were responsible for assigning patients to either the supine, lateral, or prone position groups after ESPB.

Intervention

Two specialised anaesthesiologists (TS, XDZ) blinded to group allocation performed ultrasound-guided ESPB in the ward. We placed participants in the prone position and used a high-frequency ultrasonic linear transducer (5–13 MHz; Sonosite, Bothel, WA, USA). After skin preparation, we placed the transducer 2.5–3 cm lateral to the spinous process in a parasagittal plane at the seventh thoracic vertebra (T_7). The tip of the transverse process was identified by distinguishing the contour of rib and transverse process under ultrasound. We used 2% lidocaine (2 ml) to numb the skin. Then, a short-bevelled, 22-G 80-mm nerve block needle (Stimuplex D; B. Braun, Melsungen, Germany) was used and advanced with in-plane technique from cranial to caudal. The correct needle position was assured by injecting 1 ml of saline resulting in hydro-dissection of the plane, followed by injecting a mixture of 0.375% ropivacaine and iomeprol contrast agent 30 ml (0.75% ropivacaine 15 ml, EE2403; Xianju Pharmaceutical Co., Ltd, Taizhou, Zhejiang, China; and iomeprol 15 ml, 0.3 g ml^{-1}, KP3555A; Patheon Italia S.P.A., Monza, Italy). We administered the local anaesthetic solution quickly over 30 s. After the injection, participants were maintained in their assigned position, supine, lateral, or prone, for 30 min. Patients in the lateral group maintained the operation side up. We placed a pillow beneath the upper abdomen to keep participants comfortable in the prone position group. During the procedure, SpO_2 and noninvasive blood pressure were monitored.

Outcomes

Assessment of sensory block

Cold sensation was assessed with ice 30 min after ESPB and compared with the contralateral area by the same anaesthesiologist. If participants received bilateral ESPB, the inner upper arm was considered as contrast area of cold sensation assessment. We followed studies to segment skin innervated by dermatomes of thoracic 2–12 and lumbar 1 into 29 regions.[17,26] The dermatomal sensation loss to cold of the ipsilateral thoracoabdominal wall was assessed at the midclavicular line, anterior-axillary line, midaxillary line, posterior-axillary line, and interscapular midline. Sensation was graded as 0 (no sensation), 1 (decreased sensation), or 2 (normal). A sensory block of the dermatome was considered if the grade was either 0 or 1.

CT imaging study

Participants walked to the radiology department where a CT scan of the thoracic region, partially extended to the lower neck and upper abdomen, was performed immediately after a sensation test. The thickness of image slices was set to 2 mm. Three-dimensional digital reconstruction of the local anaesthetic–contrast solution distribution was obtained. Spread of the injectate was evaluated and interpreted by the same blinded radiologist. Patients were transferred back to the ward using a wheelchair after pulmonary nodules localisation.

The primary outcome was local anaesthetic–contrast injectate spread to the paravertebral space. Secondary outcomes were: (1) spread to the neural foramina, (2) craniocaudal spread, (3) spread to the epidural space, and (4) spread to the intercostal space.

Statistical analysis

Determination of sample size was based on the thoracic level of contrast spread to the paravertebral space. Utilising PASS 11.0 software (NCSS, Kaysville, USA), we calculated the sample size according to our preliminary results. The mean thoracic level of paravertebral space spread was 2.7, 4.7, and 4.7 level, with common standard deviation (SD) of 2.6 for the supine, lateral, and prone groups, respectively. The calculated sample size was 25 participants in each group, with a power of 80% and an alpha error of 5%. The total required recruitment was 84 participants, accounting for a dropout of 10%.

All statistical analyses were performed using R packages version 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria). *P*-values were two-sided, and $P<0.025$ was considered statistically significant. Qualitative data were described using

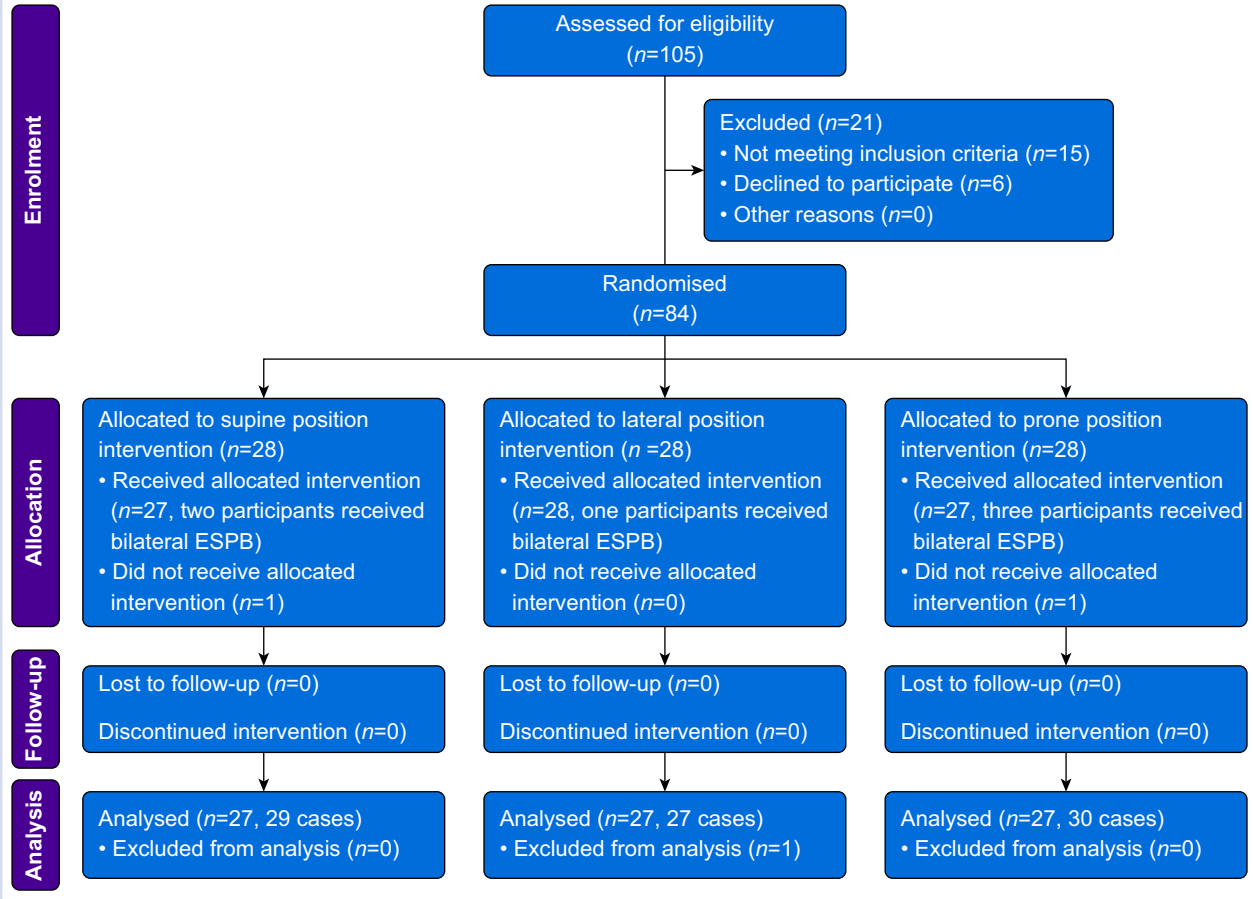

Fig 1. Study flow diagram of patient recruitment. ESPB, erector spinae plane block.

n (%), mean (SD) or median (25–75% range). For quantitative variables, we used analysis of variance, Tukey's honest significant difference test, and Kruskal–Wallis rank sum test method for multiple comparisons. For categorical variables, we used the χ^2 test or Fisher's exact test to compare between different groups. We conducted an analysis to determine the Spearman's correlation coefficient, which quantifies the linear relationship between the extent of contrast spread in the paravertebral and intercostal spaces and craniocaudal spread.

Results

We allocated 84 participants to receive an ESPB. One participant each did not receive ESPB in the prone and supine groups for a total of 82 receiving an ESPB. In the lateral position group, one participant received a CT scan 2.5 h after ESPB, and was thus excluded from analysis. Three participants in the prone group and two participants in the supine group received bilateral ESPB for bilateral pulmonary nodule positioning. One participant in the lateral position group received bilateral ESPB. We only included the upper side for analysis to keep consistent. Finally, 81 participants completed the trial and 86 ESPBs were obtained and analysed (Fig. 1 and Table 1).

Sensation assessment

Sensation levels to cold were variable in the different position groups (Fig. 2).

Table 1 Participant characteristics. Values are mean (SD) or number, except age which is presented as range.

	Supine position	Lateral position	Prone position	P value
Sex (male/female)	9/18	8/19	9/18	0.944
Age (yr)	60.0 (28–77)	57.2 (39–72)	60.6 (24–78)	0.517
Height (cm)	161.9 (7.3)	162.0 (6.8)	162.9 (7.9)	0.859
Weight (kg)	63.8 (10.7)	65.1 (9.2)	61.5 (12.0)	0.470
BMI (kg m^{-2})	24.3 (3.5)	24.7 (2.7)	23.0 (3.0)	0.105
Left/right side	15/14	18/9	12/18	0.131

Radiological assessment of injectate spread by CT

After CT scan, three-dimensional reconstruction was obtained (Fig. 3). The injectate spread consistently in the craniocaudal thoracic level. The local anaesthetic–contrast mixture extended to the paravertebral space, intercostal space, and neural foramina (Table 2, Supplementary Fig. S1).

Radiological assessment of injectate spread by CT in different position groups

There were no significant differences in the incidence of contrast spread among the three groups. Prone positioning consistently allowed paravertebral and intercostal spread in all cases, with more thoracic level spread compared with supine positioning. Injectate extended further into the intercostal space in the prone position than in the supine and lateral position groups (Fig. 4, Table 2; Supplementary Table S1).

Correlation analysis

No significant positive correlation was observed between the extent of contrast spread in the paravertebral and intercostal spaces and craniocaudal spread between the different position groups (Supplementary Table S2).

Discussion

We evaluated the spread of local anaesthetic–contrast injectate using CT scanning in participants maintained in the supine, lateral, or prone position for 30 min after ESPB. The injectate spread to the paravertebral and intercostal spaces in over 90% participants after ESPB. The local anaesthetic spread consistently to the paravertebral and intercostal space with more thoracic levels in the prone position group than in the supine position group. Nevertheless, loss of sensation in the anterior and lateral abdominal and chest wall was highly variable.

The anterior extent of injection after ESPB is variable. Anatomical studies exploring the spread of injectate show conflicting results.[4,9,27] Muscle contraction and negative pressure during respiration might contribute to the spread of local anaesthetic to the paravertebral space.[2] Thus, performing ESPB after tracheal intubation might attenuate spread. We performed ESPB while maintaining spontaneous respiration,

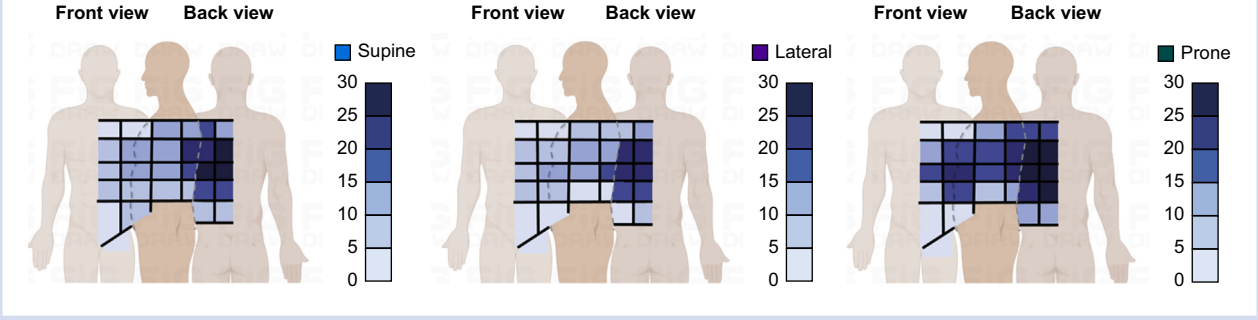

Fig 2. Sensory loss to cold in the three position groups. The intensity of colour correlates positively with success rate; a deeper shade signifies a higher likelihood of successful sensory loss.

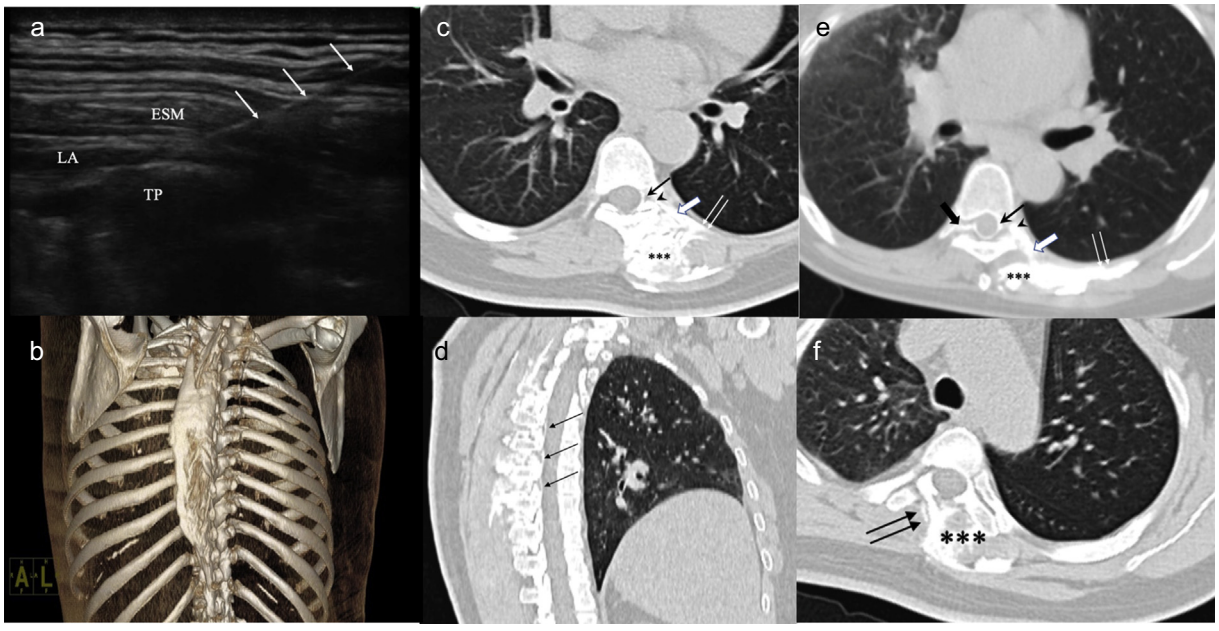

Fig 3. Ultrasound and CT image of contrast spread of erector spinae plane block (ESPB). (a) Ultrasound-guided ESPB. ESM, erector spinae muscle; LA, local anaesthetic; TP, transverse process. White arrows indicate the needle. (b) Three-dimensional reconstruction by CT (posteroanterior view) of the craniocaudal spread of local anaesthetic–contrast mixture. (c) Axial CT image at the T_7 level. The injectate enhanced by iomeprol is seen spreading to the intercostal space (white, line arrows). The paravertebral space (white, bold arrow), neural foramen (arrowhead), and erector spinae muscle (black asterisks) are also shown. Epidural spread of the injectate is indicated by the black, line arrow. (d) Sagittal CT image. Epidural spread of the injectate is indicated by the line arrows. (e) Axial CT image at the T_8 level. The injectate enhanced by iomeprol is seen spreading to the intercostal space (white, line arrows). The paravertebral space (white, bold arrow), neural foramen (black arrowhead), and erector spinae muscle (black asterisks) are also shown. The ipsilateral epidural spread of the injectate is indicated by the black, line arrow. Contralateral neural foramen and epidural spread of the contrast is indicated by the black, bold arrow. (f) Axial CT image at the T_5 level. The injectate enhanced by iomeprol is seen spreading to the erector spinae muscle (black asterisks). Contralateral spread of the contrast to the erector spinae muscle is indicated by black, line arrows.

Table 2 Incidence (upper rows) and thoracic levels of local anaesthetic–contrast injectate spread (lower rows) in the three position groups. Values are *n* (%) of cases and mean (SD). CI, confidence interval. Compared with supine position group, *P<0.025, †P<0.025, ‡P<0.001.

Local anaesthetic –contrast spread	Supine position (*n*=29)	Lateral position (*n*=27)	Prone position (*n*=30)	All positions (*n*=86)	Supine *vs* lateral	Supine *vs* prone	Lateral *vs* prone	*P* value
					Difference (95% CI)			
Paravertebral space	27 (93.1%)	26 (96.3%)	30 (100%)	83 (96.5%)				0.981
	3.1 (1.7)	4.3 (1.5)	5.0 (1.9)*	4.1 (1.9)	1.2 (0.1–2.3)	1.9 (0.8–3.0)[b]	0.7 (−0.4–1.8)	<0.001
Neural foramina	20 (70.0%)	20 (74.1%)	27 (90.0%)	67 (77.9%)				0.778
	1.4 (1.4)	1.9 (1.6)	2.8 (1.9)*	2.1 (1.7)	0.5 (−0.5–1.6)	1.4 (0.4–2.5)	0.9 (−0.1–2.0)	0.005
Craniocaudal level	29 (100%)	27 (100%)	30 (100%)	86 (100%)				1
	10.5 (2.4)	10.6 (2.1)	10.3 (1.9)	10.4 (2.1)	0.1 (−1.3–1.5)	0.1 (−1.3–1.4)†	0.2 (−1.2–1.6)	0.927
Epidural space	4 (13.8%)	5 (18.5%)	11 (36.7%)	20 (23.3%)				0.234
	0.4 (1.2)	0.3 (0.7)	0.7 (1.1)	0.5 (1.0)	0.1 (−0.5–0.8)	0.3 (−0.4–0.9)	0.4 (−0.3–1.0)	0.423
Intercostal space	28 (96.6%)	23 (85.2%)	30 (100%)	81 (94.2%)				0.910
	3.2 (1.5)	2.6 (1.5)	4.3 (1.3)*	3.4 (1.6)	0.7 (−0.3–1.6)	1.0 (0.1–1.9)†	1.7 (0.8–2.6)‡	<0.001

which showed local anaesthetic spread to the paravertebral and intercostal spaces in most cases. Nevertheless, previous imaging studies showed different results. A CT imaging study revealed that 30% and 40% of cases showed spread to paravertebral and intercostal spaces, respectively.[12] In another CT imaging study,[13] the drug reached the paravertebral (20%) and intercostal (30%) spaces in very few segments. Paravertebral space spread was also seen in two case reports involving chronic pain management.[28,29] In our trial, the paravertebral and intercostal space spread was observed in all cases in the prone position group. Notably, the extent of thoracic level spread to the paravertebral space, intercostal space, and

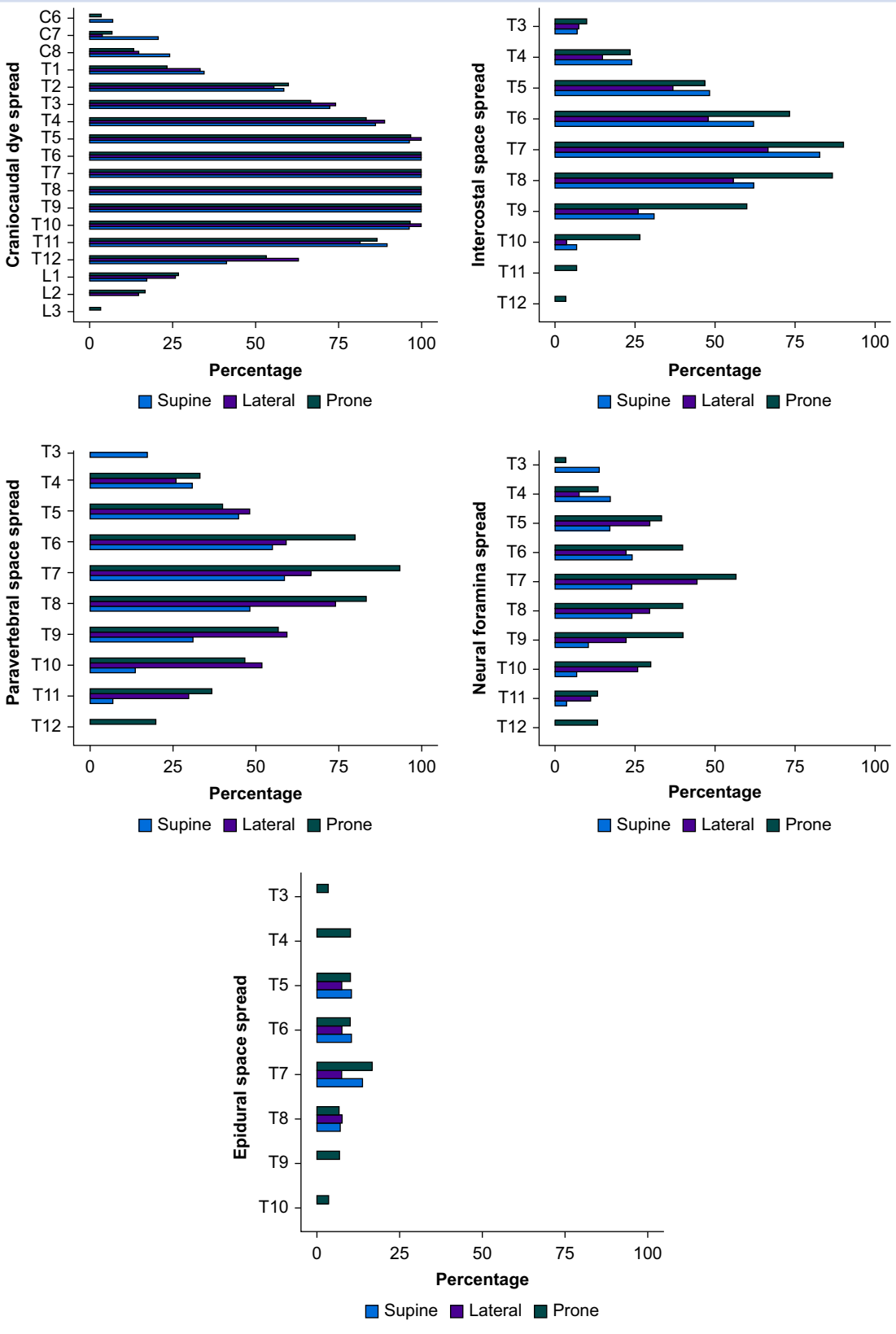

Fig 4. Local anaesthetic–contrast spread in different position groups.

neural foramina was also enhanced. We speculate that this might be attributed to the effect of gravity. When participants are placed in the prone position, gravity might promote the local anaesthetic–contrast to extend to the paravertebral space, whereas in the supine position gravity is a counteracting force keeping local anaesthetic from spreading to the paravertebral space. Our trial corresponds with many of the MRI findings in ESPB,[10,11] which showed spread of local anaesthetic–contrast to the paravertebral space, opposite to many CT imaging studies.[12,13,30]

A previous study revealed that the costotransverse foramen was the initial anterior pathway of local anaesthetic spread.[31] Micro-CT imaging has also demonstrated slits in the paravertebral region allowing communication between the retrosuperior costotransverse ligament space and the thoracic paravertebral, intervertebral, costotransverse, and erector spinae spaces.[5] Based on the present anatomical findings, multiple factors might influence the spread of local anaesthetic in ESPB including the injection site, volume used,[32] speed of injection, block needle[23,33] and use of a combination technique.[22]

Injection speed could significantly influence the distribution of local anaesthetic within an interfascial plane block. If the pressure is too high, it might disrupt the fascial layers, leading to leakback and intramuscular dispersion. Conversely, injection pressure that is too low might fail to overcome resistance of the fascia to hydro-dissection, thereby limiting spread of the local anaesthetic and potentially reducing efficacy of the block. With higher injection speed, anterior spread of local anaesthetic after ESPB might be enhanced. In a previous anatomical study, 20 ml injected during a standardised period of 2 min on each side of cadavers[9] showed poor spread to the paravertebral region after ESPB. We previously evaluated the effect of three injection speeds (20, 30, or 40 ml min^{-1}) on postoperative pain. The results showed reduced pain score with higher injection speed. Thus, we delivered a high injection speed to attempt to promote local anaesthetic spread. Our results showed optimal spread of local anaesthetic to the paravertebral and intercostal spaces. Thus, low injection speed could be a reason for the poor anterior spread in previous studies.

The increased volume of local anaesthetic and contrast medium used might be a possible reason for optimal spread in our trial. There is no consensus regarding recommendations for injectate volume, and how volume is related to injectate spread.[8] A volume of 20 ml is frequently used in both anatomic studies and clinical settings, but the level of spread and subsequent analgesic impact can be variable.[6,9,12] Therefore, additional evidence is needed to clarify how injectate volume influences spread of local anaesthetic, particularly with large volumes (≥30 ml). However, increased volume might contribute to local anaesthetic spread[34] and analgesic efficacy of ESPB.[32] We used a volume of 30 ml in our trial, consistent with two MRI studies that used 30 ml or 35 ml and showed consistent spread to the paravertebral space.[10,11] Previous studies used a volume of 20 ml, which showed suboptimal anterior spread.[20,21] However, an increase in the volume of local anaesthetic to 40 ml with CT assessment enhanced the paravertebral and epidural space spread.[20] Despite the volume of local anaesthetic used, the contrast volume was still 5 ml of Omnipaque. Although only 2 ml of iohexol was used by Chen and colleagues,[13] they showed suboptimal paravertebral space spread. The amount of contrast used might influence the recognition of paravertebral spread. Preliminary testing revealed difficulty in discerning paravertebral structures from the contrast owing to their similar grey scale on CT imaging.[12,13] Consequently, we increased iomeprol concentration to enhance contrast recognition. However, this augmentation might increase the viscosity of the local anaesthetic–contrast mixture, potentially attenuating spread through the connective tissue to the paravertebral space.

We found inconsistent loss of sensation to cold in the lateral and anterior chest wall unlike other classic nerve block techniques. Our findings were consistent with many previous studies,[7,35] whereas other studies show consistent loss of sensation on the anterior or lateral chest wall in all subjects.[10,36] The discrepancy between clinical analgesia and cutaneous sensory block could be the result of differential nerve block.[37,38] In particular, when intact nerves are exposed to low concentrations of local anaesthetic, C nerve fibres are preferentially blocked compared with A_δ nerve fibres. Therefore, the change in sensation might not be detected by common sensory testing, which in turn might underestimate the clinical analgesic effect.[39,40] However, the proposed differential block after ESPB might be unlikely, has never been demonstrated, and thus lacks sufficient evidence.[41,42] Although ESPB failed to exhibit many of the classic characteristics of a peripheral nerve block with its mismatch of sensory block and clinical analgesia. Our results provide new evidence that local anaesthetic can spread into the paravertebral and intercostal spaces in ESPB. The expected spread to paravertebral or intercostal spaces and sensory loss can be enhanced in the prone or lateral positions.

Our trial has several limitations. Firstly, we performed CT imaging 30 min after ESPB, a prolonged time interval with unknown effect on the anterior spread of local anaesthetic. Meanwhile, we did not assess patient comfort scale while maintaining positions for 30 min. Secondly, we did not evaluate the influence of different positions after ESPB on haemodynamic changes. Thirdly, we failed to compare the analgesic effect of ESPB post-procedure owing to the uncontrollable time interval from ESPB to the beginning of operation. Finally, our sample size was not large enough to detect statistical significance between the difference in contrast spread in the prone and lateral positions. To substantiate the robustness of our findings, future research ought to address the limitations of our trial to broaden applicability of our results.

Conclusions

In summary, local anaesthetic–contrast injectate spread to the paravertebral space, neural foramina, and intercostal space was common but variable after ESPB. Prone positioning after ESPB block contributed to spread to the paravertebral and intercostal spaces and neural foramina. Nevertheless, sensory block of the anterior and lateral abdominal and chest wall was highly variable. This provides new insights to improve the stability of anterior spread of local anaesthetic in ESPB.

Authors' contributions

Conception and study design: HGB, CS, TS, XDZ, ZZY
Study conduct: TS, XDZ, LH, ZZY, JY
Data analysis and interpretation: XZ, QLT, CS, LH
Drafting of the manuscript: TS, XDZ
Critical revision of the manuscript: all authors
Approval of the manuscript: all authors

Declaration of interest

The authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2024.10.046.

References

1. Forero M, Adhikary SD, Lopez H, Tsui C, Chin KJ. The erector spinae plane block: a novel analgesic technique in thoracic neuropathic pain. *Reg Anesth Pain Med* 2016; **41**: 621–7
2. Chin KJ, El-Boghdadly K. Mechanisms of action of the erector spinae plane (ESP) block: a narrative review. *Can J Anaesth* 2021; **68**: 387–408
3. Lonnqvist PA, Karmakar MK, Richardson J, Moriggl B. Daring discourse: should the ESP block be renamed RIP II block? *Reg Anesth Pain Med* 2021; **46**: 57–60
4. Adhikary SD, Bernard S, Lopez H, Chin KJ. Erector spinae plane block versus retrolaminar block: a magnetic resonance imaging and anatomical study. *Reg Anesth Pain Med* 2018; **43**: 756–62
5. Cho TH, Kwon HJ, O J, Cho J, Kim SH, Yang HM. The pathway of injectate spread during thoracic intertransverse process (ITP) block: micro-computed tomography findings and anatomical evaluations. *J Clin Anesth* 2022; **77**, 110646
6. Dautzenberg KHW, Zegers MJ, Bleeker CP, et al. Unpredictable injectate spread of the erector spinae plane block in human cadavers. *Anesth Analg* 2019; **129**: e163–6
7. Byrne K, Smith C. Human volunteer study examining the sensory changes of the thorax after an erector spinae plane block. *Reg Anesth Pain Med* 2020; **45**: 761–2
8. Ivanusic J, Konishi Y, Barrington MJ. A cadaveric study investigating the mechanism of action of erector spinae blockade. *Reg Anesth Pain Med* 2018; **43**: 567–71
9. Yang HM, Choi YJ, Kwon HJ, O J, Cho TH, Kim SH. Comparison of injectate spread and nerve involvement between retrolaminar and erector spinae plane blocks in the thoracic region: a cadaveric study. *Anaesthesia* 2018; **73**: 1244–50
10. Schwartzmann A, Peng P, Maciel MA, Alcarraz P, Gonzalez X, Forero M. A magnetic resonance imaging study of local anesthetic spread in patients receiving an erector spinae plane block. *Can J Anaesth* 2020; **67**: 942–8
11. Sorenstua M, Zantalis N, Raeder J, Vamnes JS, Leonardsen AL. Spread of local anesthetics after erector spinae plane block: an MRI study in healthy volunteers. *Reg Anesth Pain Med* 2023; **48**: 74–9
12. Abdella A, Arida E, Megahed NA, El-Amrawy WZ, Mohamed WMA. Analgesia and spread of erector spinae plane block in breast cancer surgeries: a randomized controlled trial. *BMC Anesthesiol* 2022; **22**: 321
13. Chen Q, Yang H, Zhao D, Tang X, Liu H. Anesthetic spread of ultrasound-guided paraspinal blocks in video-assisted thoracoscopic surgery: a three-dimensional reconstruction image study. *Pain Physician* 2023; **26**: E383–7
14. Coppens S, Eochagain AN, Hoogma DF, Dewinter G. Stranger things: the erector spinae block, extra sensory perception, or paranormal block by proxy? *Anesthesiol Perioper Sci* 2023; **1**: 12
15. Hoogma DF, Van den Eynde R, Oosterlinck W, et al. Erector spinae plane block for postoperative analgesia in robotically-assisted coronary artery bypass surgery: results of a randomized placebo-controlled trial. *J Clin Anesth* 2023; **87**, 111088
16. Hoogma DF, Van den Eynde R, Al Tmimi L, et al. Efficacy of erector spinae plane block for minimally invasive mitral valve surgery: results of a double-blind, prospective randomized placebo-controlled trial. *J Clin Anesth* 2023; **86**, 111072
17. Xu ZZ, Li X, Chen BL, et al. A randomised controlled trial of the non-inferiority of erector spinae plane block vs. thoracic paravertebral block for laparoscopic nephroureterectomy. *Anaesthesia* 2023; **78**: 442–8
18. Moorthy A, Ni Eochagain A, Dempsey E, et al. Postoperative recovery with continuous erector spinae plane block or video-assisted paravertebral block after minimally invasive thoracic surgery: a prospective, randomised controlled trial. *Br J Anaesth* 2023; **130**: e137–47
19. De Lara Gonzalez SJ, Pomes J, Prats-Galino A, Gracia J, Martinez-Camacho A, Sala-Blanch X. Anatomical description of anaesthetic spread after deep erector spinae block at L-4. *Rev Esp Anestesiol Reanim (Engl Ed)* 2019; **66**: 409–16
20. Diwan S, Garud R, Nair A. Thoracic paravertebral and erector spinae plane block: a cadaveric study demonstrating different site of injections and similar destinations. *Saudi J Anaesth* 2019; **13**: 399–401
21. Elsharkawy H, Bajracharya GR, El-Boghdadly K, Drake RL, Mariano ER. Comparing two posterior quadratus lumborum block approaches with low thoracic erector spinae plane block: an anatomic study. *Reg Anesth Pain Med* 2019; **44**: 549–55
22. Sartawi RY, McLeod G, Mustafa A, Lamb C. Randomized trial comparing the spread of erector spinae block with the combination of erector spinae block and retrolaminar block in soft embalmed Thiel cadavers. *Reg Anesth Pain Med* 2021; **46**: 1061–6
23. McLeod G, Sartawi R, Chang C, Mustafa A, Raju P, Lamb C. Craniocaudal spread and clinical translation for combined erector spinae plane block and retrolaminar block in soft embalmed cadavers: a randomised controlled equivalence study. *Br J Anaesth* 2024; **132**: 1146–52
24. Hong JM, Kim E, Jeon S, et al. A prospective double-blinded randomized control trial comparing erector spinae plane block to thoracic epidural analgesia for postoperative pain in video-assisted thoracic surgery. *Saudi Med J* 2023; **44**: 155–63
25. Durey B, Djerada Z, Boujibar F, et al. Erector spinae plane block versus paravertebral block after thoracic surgery for lung cancer: a propensity score study. *Cancers (Basel)* 2023; **15**: 2306
26. Kirshblum SC, Burns SP, Biering-Sorensen F, et al. International standards for neurological classification of spinal cord injury (revised 2011). *J Spinal Cord Med* 2011; **34**: 535–46
27. Vidal E, Gimenez H, Forero M, Fajardo M. Erector spinae plane block: a cadaver study to determine its mechanism

of action. *Rev Esp Anestesiol Reanim (Engl Ed)* 2018; **65**: 514–9
28. Diwan S, Nair A. Is paravertebral-epidural spread the underlying mechanism of action of erector spinae plane block? *Turk J Anaesthesiol Reanim* 2020; **48**: 86–7
29. Hernandez-Porras BC, Rocha A, Juarez AM. Phenol spread in erector spinae plane block for cancer pain. *Reg Anesth Pain Med* 2020; **45**: 671
30. Xu X, Xie YX, Zhang M, Du JH, He JX, Hu LH. Comparison of thoracoscopy-guided thoracic paravertebral block and ultrasound-guided thoracic paravertebral block in postoperative analgesia of thoracoscopic lung cancer radical surgery: a randomized controlled trial. *Pain Ther* 2024; **13**: 577–88
31. Bonvicini D, Boscolo-Berto R, De Cassai A, et al. Anatomical basis of erector spinae plane block: a dissection and histotopographic pilot study. *J Anesth* 2021; **35**: 102–11
32. Zengin M, Sazak H, Baldemir R, et al. Comparison of analgesic efficacy of different local anesthetic volumes for erector spinae plane block in thoracotomy patients; a prospective randomized trial. *BMC Anesthesiol* 2023; **23**: 42
33. Fusco P, Pascarella G, Stecco C, et al. Factors to consider for fascial plane blocks' success in acute and chronic pain management. *Minerva Anestesiol* 2024; **90**: 87–97
34. Gadsden J, Gonzales J, Chen A. Relationship between injectate volume and disposition in erector spinae plane block: a cadaveric study. *Reg Anesth Pain Med* 2024; **49**: 511–7
35. Zhang J, He Y, Wang S, et al. The erector spinae plane block causes only cutaneous sensory loss on ipsilateral posterior thorax: a prospective observational volunteer study. *BMC Anesthesiol* 2020; **20**: 88
36. Barrios A, Camelo J, Gomez J, et al. Evaluation of sensory mapping of erector spinae plane block. *Pain Physician* 2020; **23**: E289–96
37. Pawa A, King C, Thang C, White L. Erector spinae plane block: the ultimate 'plan A' block? *Br J Anaesth* 2023; **130**: 497–502
38. Pawa A, White L. Pro: the erector spinae plane block is useful for thoracic surgery. *J Clin Anesth* 2024; **92**, 111300
39. Ford DJ, Raj PP, Singh P, Regan KM, Ohlweiler D. Differential peripheral nerve block by local anesthetics in the cat. *Anesthesiology* 1984; **60**: 28–33
40. Sorenstua M, Leonardsen AL, Chin KJ. Dorsal root ganglion: a key to understanding the therapeutic effects of the erector spinae plane (ESP) and other intertransverse process blocks? *Reg Anesth Pain Med* 2024; **49**: 223–6
41. Karmakar MK, Lonnqvist PA. The clinical use of the thoracic erector spinae plane block. Con - ESPB is not useful for thoracic analgesia. *J Clin Anesth* 2024; **93**, 111353
42. Sivakumar RK, Luckanachanthachote C, Karmakar MK. Differential nerve blockade to explain anterior thoracic analgesia without sensory blockade after an erector spinae plane block may be wishful thinking. *Reg Anesth Pain Med* 2024; **49**: 536–9

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