Prospective Study

Anesthetic Spread of Ultrasound-Guided Paraspinal Blocks in Video-Assisted Thoracoscopic Surgery: A Three-Dimensional Reconstruction Image Study

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Background: Anesthetic spread of ultrasound-guided paraspinal blocks is still unknown.

Objectives: To compare the drug diffusion qualities of intertransverse process block (ITPB) and erector spinae plane block (ESPB) in clinical practice.

Study Design: Prospective computed tomography (CT)-3-dimensional (3D) reconstruction image study.

Setting: Operation room in hospital.

Methods: Twenty patients undergoing thoracoscopic pulmonary wedge resection or segmentectomy were enrolled. These procedures require localization of pulmonary nodules using CT-guided needle puncture immediately before surgery. The patients were divided into 2 groups, each consisting of 10 patients. Group I underwent ITPB, while group E underwent ESPB. These interventions were performed 30 minutes before surgery using 20 mL of 0.25% bupivacaine with 2 mL iohexol. Sensory loss of the thoracic dermatomes was assessed using cold stimulation before general anesthesia. Patients' CT localization images were used for 3D reconstruction after surgery, and the diffusion of the drug in each cross-section of the CT images was evaluated.

Results: Three-dimensional imaging of the drug showed that in group E, drug diffusion was improved in the cephalocaudal area compared to group I (10 vs 4.5 segments). Drug diffusion in group I was improved anteriorly and laterally ([10/10, 100%] in the paravertebral and intercostal spaces) and reached the front of the vertebral body along the thoracic fascia in certain segments (6/10, 60%). In group E, very few segments of the drug reached the paravertebral (2/10, 20%) and intercostal (3/10, 30%) spaces. All patients in group I had clear signs of loss of cold sensation on the lateral and anterior chest walls, with an average of 4 thoracic dermatomes. In group E, 3 patients had definite lateral and anterior chest wall cold stimulation signs, the thoracic dermatome was discontinuous, and the effect was only present between 1-2 segments. The blocking effect of the paraspinal zone was excellent (100%) in both groups.

Limitations: However, this study has some limitations. First, the sample size was small, and clinical trials with larger samples are required to further verify the effects of ITPB and ESPB. Second, the same local anesthetic drug concentration and volume were used for both techniques in this study, and the effect of volume or concentration on drug diffusion was not further explored.

Conclusions: Compared with ESPB, ITPB yielded increased stability in lateral and anterior chest wall block with improved anterior and intercostal spread, but reduced cephalocaudal spread.

Key words: Erector spinae plane block, intertransverse process block, 3-dimensional imaging, paraspinal block, drug diffusion, video-assisted, thoracoscopic surgery, 3D reconstruction

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Paravertebral block (PVB) is currently considered a reliable analgesic in thoracic and breast surgery (1,2). Although the PVB can block sympathetic nerves, the puncture process is deep and very close to the pleura and vessels, producing a risk of pneumothorax and paravertebral hematoma (3,4). Therefore, the superficial blocking technique is preferred if a similar analgesic effect can be achieved.

In 2016, the erector spinae plane block (ESPB) was first described by Forero et al (5); this is a safe and easily implemented technique for indirect PVB. A recent study (6) confirmed that preoperative ESPB may provide an equivalent analgesia and quality of recovery after breast surgery compared to preoperative PVB. In ESPB, the deep fascial plane of the erector spinae muscle is the injection site of local anesthetics, which is distant from the pleura and neuraxial structures (5). However, the reliability and reproducibility of the ESPB remain poor, and its effectiveness should be further addressed in future research. Anatomical dissections, radiological imaging, or paravertebral endoscopy have been used to demonstrate the precise diffusion of local anesthetics, but researchers have reported conflicting evidence on this issue (7-9). The intertransverse process block (ITPB) is a paraspinal block carried out by injection posterior to the superior costotransverse ligament (SCTL) in the tissue between 2 transverse processes (10). These approaches have a drug injection point deeper than that of the ESPB, but follow a similar longitudinal in-plane approach.

Current research on these techniques is mainly focused on autopsy, and there is no drug diffusion study in clinical practice. In this study, thoracoscopic lung surgery requiring immediate preoperative computed tomography (CT) localization was selected. Additionally, 3-dimensional (3D) imaging technology was used to observe the drug diffusion after the 2 techniques to find a superficial block technique that can replace PVB.

Methods

This prospective CT-3D reconstruction image study was performed on patients undergoing thoracoscopic pulmonary wedge resection or segmentectomy from January 2022 to May 2022. These procedures required localization of pulmonary nodules using a CT-guided needle puncture immediately before the surgery was conducted. The exclusion criteria were as follows: 1) history of spinal injury; 2) history of contrast medium-induced anaphylaxis; 3) severe cerebrovascular disease; and 4) body mass index > 30 or < 18. This study was approved by the Institutional Review Board (approval number CZLS2018041) and registered at ClinicalTrials.gov (registration number ChiCTR2200055394). All patients were informed of relevant matters related to the procedure and the risks involved one day before surgery. All patients signed an informed consent form.

Each patient entered the anesthesia preparation room 40 minutes before surgery. The following parameters were monitored using standard intraoperative methods: peripheral oxygen saturation, continuous electrocardiographic values, and noninvasive blood pressure. The patients were divided using the random number method into 2 groups: the ESPB group (group E, n = 10) and the ITPB group (group I, n = 10). The patients were placed in the lateral decubitus position with the surgical side above. The same experienced anesthesiologist performed all the nerve blocks; this anesthesiologist specializes in regional anesthesia and pain medicine.

A high-frequency linear (12 MHz) ultrasound probe (Mindray M9; Bio-Medical Electronics, Shenzhen, China) was positioned 2-4 cm lateral to the tip of the spinous process in a longitudinal orientation with a segment of the surgical incision. The structures were visualized in the sagittal plane with the erector spinae, transverse process, intertransverse ligament, retro-SCTL space (RS), SCTL, paravertebral space, and pleura, from superficial to deep (Fig. 1). In group E, an 22-G 8-cm block needle (Braun, Aschaffenburg, Germany) was inserted until the tip advanced toward the interfascial plane between the erector spinae muscles and transverse process in a cephalad-caudad direction. In group I, the tip reached the RS space between the intertransverse ligament and SCTL. Twenty milliliters of 0.25% bupivacaine with 2 mL iohexol were administered at this site.

After the nerve block procedure was conducted, the patients were placed in the supine position and, 30 minutes later, immediately before entering the operating room, the extent of sensory loss was assessed with cold stimulation, including the anterior chest wall (midclavicular line), lateral chest wall (posterior axillary line), and posterior chest wall (paraspinal zone) by a researcher who was blinded to group allocation (Fig. 2).

General anesthesia was achieved with midazolam (1-2 mg), propofol (2-3 mg/kg), sufentanil (0.3-0.4 μg/kg), and rocuronium (0.6-0.7 mg/kg). Anesthesia was maintained with a continuous infusion of propofol (1.5-3 mg/kg/h), sevoflurane (1-2 vol %), and remifentanil (0.05-0.1 μg/kg/min) after the patient entered the

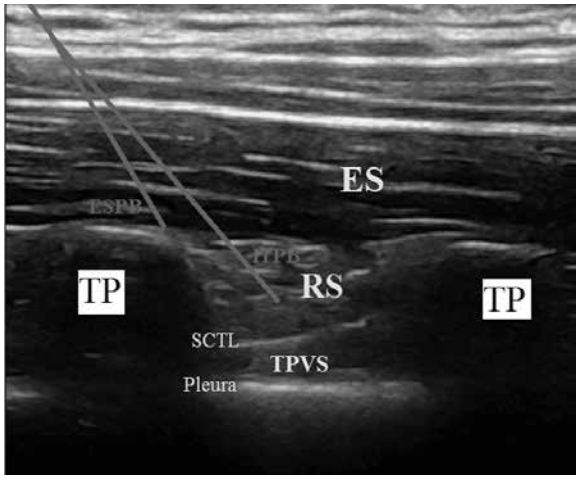

Fig. 1. *Ultrasound images of ITPB and ESPB.*
ITPB, intertransverse process block; ESPB, erector spinae plane block.

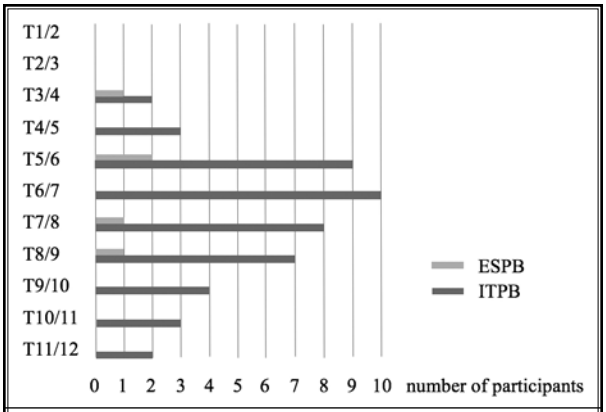

Fig. 2. *Sensory loss of thoracic dermatomes during the cold stimulation test on the lateral chest wall after 30 minutes of ultrasound-guided nerve block.*

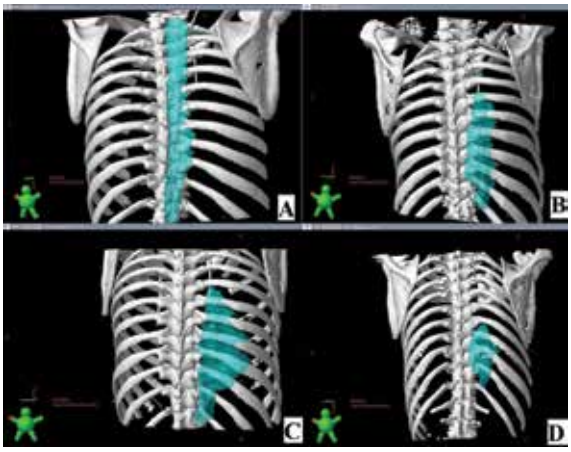

Fig. 3. *Examples of adequate and poor diffusion of the drug via ITPB compared with ESPB in frontal view.*
A: adequate image-ESPB; B: poor image-ESPB; C: adequate image-ITPB; D: poor image-ITPB. Green area: local anesthetic.
ITPB, intertransverse process block; ESPB, erector spinae plane block.

operating room. After anesthesia induction, a left-side double-lumen endotracheal tube was inserted under video laryngoscopy (32-35 Fr for women and 35-37 Fr for men). The Olympus BF 3C30-type fiber optic bronchoscope (Olympus, New Hyde Park, NY) was used to verify the appropriate depth of the double-lumen endotracheal tube immediately after intubation. The patients were then carefully placed in the lateral decubitus position, and the surgeons performed pulmonary nodule localization via CT-guided needle puncture. CT images were used for 3D reconstruction with the Eclipse software (Varian Medical Systems, Palo Alto, CA) after surgery. The diffusion of the drug in each cross-section of the CT images was initially identified by the software. The imaging density of the drug between the bone and muscle was then reviewed by 2 radiologists.

Results

Twenty patients (10 per group) were enrolled in this study. The 3D imaging results of the drug showed that, in group E, drug diffusion to the cephalocaudal area was improved compared to group I, and the average diffusion segment reached 10. Conversely, in group I, the average diffusion segment was 4.5. The images showing the craniocaudal spread in both groups are shown in Fig. 3. Compared with group E, drug diffusion in group I was improved anteriorly and laterally, reaching the paravertebral space (10/10, 100%) and the front of the vertebral body along the thoracic fascia in certain segments (6/10, 60%). In group E, very few segments of the drug reached the paravertebral space (2/10, 20%) and intercostal space (3/10, 30%) (Fig. 4).

The results of cold stimulation 30 minutes after the nerve block procedure showed similarities to the diffused segment reconstructed 3-dimensionally using the drug. Lateral and anterior chest wall block effects had increased stability in group I. All patients in group I had clear signs of loss of cold sensation on the lateral and anterior chest walls, with an average of 4.8 thoracic dermatomes. In contrast, in group E, the blocking effect of the contralateral chest wall and anterior chest

wall was discontinuous and unstable. Only 3 patients showed definite signs of lateral and anterior chest wall cold stimulation. Furthermore, the thoracic dermatome was discontinuous, and the effect was between 1-2 segments. The blocking effect of the paraspinal zone was excellent in both groups (100% vs 100%) (Fig. 5).

Discussion

The 3D images confirmed that the ESPB spread widely cranially and caudally, with an average spread of 10 segments. However, the spread reduced in the anterior paravertebral and lateral intercostal directions. For the ITPB, both the cranial and caudal spread were significantly worse than that of the ESPB, with an average spread of only 4.5 segments. Nonetheless, this method improves the spread of the drug in the paravertebral and intercostal regions. Furthermore, the blocking effect of the contralateral and anterior chest walls was more stable and effective than that of ITPB.

Compared with PVBs, paraspinal blocks are simpler to operate and have a reduced risk of pneumothorax and hematoma because the injection site is far from the pleura and paravertebral space, highlighting the potential of this technique. However, the manner of drug diffusion remains a clinically relevant question. The ITPB is a collective name for several reported block techniques, such as subtransverse process interligamentary, costotransverse foramen, midpoint transverse process to pleura, and multiple injection costotransverse blocks (11-13). These approaches have a needle endpoint located in the RS between the deep fascial plane of the ESP and SCTL. Previous studies (7,14,18) have shown that when the drug was injected into the RS, the ventral ramus and paravertebral zone of the cadavers were dyed, and a part of the sympathetic ganglion was also surrounded by dye solution (50%). The medial and lateral slits of the SCTL and the costotransverse space between the rib and the transverse process were considered potential pathways for drug infiltration (15). Our data regarding the spread of ITPB in patients undergoing thoracoscopic surgery is consistent with previous autopsy studies. Furthermore, blockade of the ventral nerve of the thoracic dermatome for cold stimuli verified the accuracy of our 3D imaging, further confirming the reliability and stability of the ITPB.

Compared with ITPB, ESPB was reported earlier and is widely used in various procedures, such as abdominal, breast, and thoracic surgery (16,17). Nonetheless, the drug diffusion pathway and clinical efficacy of this method remain unclear. Studies (7,12,14) have shown that the costotransverse foramen and ligaments are possible pathways for the spread of ESPB. However, an anterior diffusion path through the costotransverse foramen remains controversial as the complex attachment of the intertransverse ligament and costotransverse ligaments under the erector spinae muscle may prevent anterior anesthetic diffusion. Anatomical study has shown that the dye can stain the ventral branch of the thoracic nerve, while other suggest that it can only stain the dorsal branch (18,19). Our study showed that the ESPB had significantly improved craniocaudal spread compared to the anterior and intercostal spaces. Moreover, the cold stimulation block in the area innervated by the ventral nerve of the thoracic nerve was

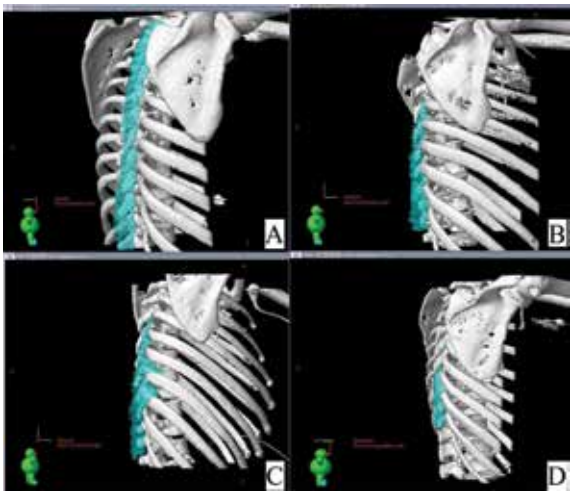

Fig. 4. *Examples of adequate and poor diffusion of the drug via ITPB compared with ESPB in lateral view.*
A: adequate image-ESPB; B: poor image-ESPB; C: adequate image-ITPB; D: poor image-ITPB. Green area: local anesthetic.
ITPB, intertransverse process block; ESPB, erector spinae plane block.

Fig. 5. *Image of ESPB and ITPB spreading into the paravertebral space, viewed from the front of the spine.*
A: ESPB; B: ITPB. Green area: local anesthetic; yellow area: superior costotransverse ligament.
ITPB, intertransverse process block; ESPB, erector spinae plane block.

discontinuous and unstable. Only the blocking effect on the dorsal collateral area was definite and stable.

This study was performed in real-life clinical practice, which reflects the clinical reality more accurately than previous autopsy studies. This is due to the changes in thoracic pressure caused by breathing or muscle tone and contraction, which can influence the spread of local anesthetic. However, this study has some limitations. First, the sample size was small, and clinical trials with larger samples are required to further verify the effects of ITPB and ESPB. Second, the same local anesthetic drug concentration and volume were used for both techniques in this study, and the effect of volume or concentration on drug diffusion was not further explored.

Conclusions

Compared with ESPB, ITPB could produce more stable lateral and anterior chest wall block effects with improved anterior and intercostal spread but reduced craniocaudal spread.

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