Two different in-plane approaches in ultrasound-guided thoracic paravertebral block using a microconvex probe, transverse vs. parasagittal

A randomised controlled trial

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Running head: Two different in-plane approaches of TPVB, transverse vs. parasagittal

<Abstract>

Background: Several approaches have been proposed for ultrasound-guided thoracic paravertebral block (TPVB), but the optimal approach remains unclear.

Objective: We compared two ultrasound-guided in-plane approaches using a microconvex probe: transverse and parasagittal. We assessed whether either approach facilitated successful catheter placement in the paravertebral space (PVS).

Design: Randomised controlled trial.

Setting: University hospital, July 2015 to March 2016.

Patients: Sixty patients scheduled to undergo thoracotomy were randomly allocated into two groups.

Interventions: A microconvex probe was placed transversally between adjacent ribs (transverse) or sagittally between adjacent transverse processes (parasagittal). When the Tuohy needle reached the PVS, a catheter was inserted to a depth of 4 cm. Then, 0.5 ml radiocontrast was injected through the catheter under fluoroscopy.

Main outcome measures: The primary outcome was successful catheter placement in the PVS; secondary outcomes were 0-100 mm visual analogue scale (VAS) pain score and morphine consumption in the first 24 h.

Results: All patients received the allocated paravertebral block. Correct catheter placement occurred in 23 (77%) and 24 patients (80%) using the transverse (*n*=30) and parasagittal approaches (*n*=30), respectively (*P*=1.00). Five patients were excluded due to changes in surgical procedure. Postoperative pain, represented by median [IQR] VAS score, was 19.5 [12 to 25] at rest and 55 [44 to 77] on movement in the transverse approach (*n*=28) vs. 22 [12 to 33.5] at rest and 59 [41.5 to 75] on movement in the parasagittal approach (*n*=27) (*P*=0.57 at rest, *P*=0.76 on movement). Median morphine consumption was 11.5 [5 to 21] and 11 [5 to 18] mg in the transverse and parasagittal approaches, respectively (*P*=0.99).

Conclusions: There were no clinically significant differences between approaches for continuous ultrasound-guided TPVB using a microconvex probe, and there was a high rate of correct catheter placement in both approaches.

Trial registration: UMIN Clinical Trials Registry identifier: UMIN000015988.

Introduction

Thoracic paravertebral block (TPVB) is a regional anaesthetic technique during which a local anaesthetic (LA) is injected into the thoracic paravertebral space (TPVS), as an alternative to thoracic epidural anaesthesia.[1-3] The TPVS is a wedge-shaped space formed medially between the vertebral bodies, intervertebral discs, and intervertebral foramen; dorsally between the superior costotransverse ligament, internal intercostal membrane, ribs, and transverse processes; and ventrally between the parietal pleura.[2-5]

Ultrasound can aid with visualisation of the TPVB by visualising the TPVS and the approaching needle in real-time.[6-15] Several techniques of ultrasound-guided TPVB have been reviewed previously.[4-5] The ultrasonic transducer is placed in a transversal or sagittal direction for a back image. In addition to these different ultrasound images, the needle is advanced into the TPVS with an in- or out-of-plane approach on the ultrasound image. An in-plane approach is safer and easier than the out-of-plane approach because it allows continuous visualisation of the full length of the needle and target site of TPVS together.

Previous studies have reported paravertebral catheter tip position using various in-plane TPVB techniques.[12-13] However, the most effective approach remains unclear. In the parasagittal in-plane approach, a steep needle insertion angle is required, and needle motion interference can occur due to the presence of the ultrasound transducer and the narrow interspace between the adjacent transverse processes.[4-5] In contrast, in the transverse in-plane approach, the insertion needle angle and needle motion are less restricted than in the parasagittal in-plane approach. Therefore, we hypothesised that the transverse in-plane approach is a better technique for catheter placement into the TPVS when compared with the parasagittal in-plane approach. Thus, this study evaluated successful catheter placement into the TPVS and postoperative analgesia between these two ultrasound-guided TPVB in-plane approaches using a radiocontrast agent via fluoroscopy.

Methods

Ethics approval and study design

Ethical approval for this randomised controlled, single-blind trial (identifier: 2014-0380) was provided by the Ethical Committee of Nagoya University Hospital, Nagoya, Japan (Chairman Prof Y. Ando) on 11 March 2015. This trial was registered at UMIN Clinical Trials Registry (identifier: UMIN000015988). Written informed consent to participate was obtained from all patients scheduled to undergo thoracotomy. This study was conducted at Nagoya University Hospital between July 2015 and March 2016.

Participants

Inclusion criteria were age ≥20 years, scheduled thoracotomy (segmentectomy or lobectomy), and ASA physical status classification (ASA-PS) class 1-2. Exclusion criteria were <20 years of age, ASA-PS class 3–6, renal dysfunction (estimated glomerular filtration rate <60 ml min^{-1} 1.73 m^{-2}), liver dysfunction (Child-Pugh score, B-C), coagulation dysfunction (platelet count <100,000 µl), international normalised ratio of prothrombin time (PT-INR) >1.5 or <70% activated partial thromboplastin time (APTT), and allergies to a radiocontrast agent or ropivacaine.

Randomisation

Participants were randomly allocated into two groups based on the TPVB approach: transverse or parasagittal. Block randomisation with a block size of ten was applied and similar numbers were provided for each group using the computer-generated randomisation software (http://www.randomization.com). The allocation was blinded for participants and the anaesthesiologist who performed the interventions was informed of the study allocation before the patient arrived in the operation room. The allocated ultrasound-guided TPVB approach was conducted under general anaesthesia before thoracic surgery.

General anaesthesia and interventions (approaches for ultrasound-guided TPVB)

General anaesthesia was induced with propofol 1.5-2.0 mg kg^{-1}, remifentanil 2 μg kg^{-1}, and ketamine 0.8-1.2 mg kg^{-1}. A double-lumen tracheal tube was intubated after administering rocuronium 0.8-1.0 mg kg^{-1}. Anaesthesia was maintained using desflurane 4-5% and remifentanil 0.05-0.1 μg kg min^{-2}.

The patient was placed in the lateral decubitus position, and ultrasound-guided TPVB was performed. First, each ultrasound image of the TPVS was visualised with a portable ultrasound machine (M-Turbo™; FUJIFILM SonoSite, Bothell, WA, USA), and an 8-5 MHz ultrasonic microconvex array transducer was placed transversally between adjacent ribs (transverse group) or sagittally at approximately 2.5 cm lateral to the midline between the adjacent transverse processes (parasagittal group). A 17-gauge Tuohy needle (Hakko Co. Ltd., Nagano, Japan) was inserted from the outer end of the transducer in a lateral-to-medial direction in the transverse group or a cranial-to-caudal or caudal-to-cranial direction in the parasagittal group (Fig. 1). Using the microconvex ultrasound probe, the entry point was located 4 cm away from the midline in the transverse group, and 2.5 cm away from the midline in the parasagittal group. The needle was advanced in-plane on the ultrasound image until the needle tip was located in the TPVS. It was ensured that the parietal pleura was pressed down ventrally by injecting 5 ml saline via the needle using the ultrasound visualisation. A catheter (radiopaque polytetrafluoroethylene catheter, with no stylet and no soft tip; Hakko Co. Ltd., Nagano, Japan) was inserted to a depth of 4 cm into the TPVS through the needle. After the catheter was fixed to the skin with 4-0 nylon sutures, the patient’s position was changed to the supine position. A 0.5-ml volume of radiocontrast agent, iohexol 240 mg kg^{-1} (Omnipaque 240™; Daiichi Sankyo Co. Ltd., Tokyo, Japan), was injected via the catheter under fluoroscopy. The location of the catheter tip was identified using the frontal and lateral views under fluoroscopy. Thereafter, the paravertebral spread was assessed by injecting 20 ml diluted contrast agent (contrast agent 10 ml + saline 10 ml) via the catheter under fluoroscopy. For postoperative pain management, the patient received a continuous infusion of 0.2% ropivacaine at 6 ml/h via the paravertebral catheter at the end of surgery. Additionally, morphine was used as a postoperative adjuvant analgesic opioid via intravenous patient-controlled analgesia (iv-PCA) (bolus dose, 1 mg; lockout interval, 5 minutes).

Outcomes measurement

The primary outcome was the correct placement of the catheter into the TPVS in each group. The catheter tip position was evaluated as follows: (1) TPVS or (2) out of TPVS (in the epidural space, back muscle, posterior mediastinum, or thoracic cavity). The course of the catheter was evaluated with the recorded images. This primary outcome was assessed by an independent anaesthesiologist who was blinded to patient allocation.

Secondary outcomes were the course of the catheter and the range of cranio-caudal spreading of the radiocontrast agent following a 20 ml radiocontrast catheter injection. Additionally, postoperative analgesia was assessed using a 0-100 mm visual analogue scale (VAS) score at rest and on movement 24 h post-surgery on a questionnaire, and morphine consumption in the first 24 h was assessed between groups.

Statistical analysis

Sample size calculation of this study revealed that a sample size of 25 participants in each group would provide 80% power (two-sided α of 0.05) to test for an expected 0.35 improvement in the proportion of patients with the catheter tip position in the TPVS. This value was calculated from a previous study assessing the parasagittal in-plane approach.[12] We expected a 15% attrition rate in this study; therefore, we sought to include 60 participants.

We assessed the catheter tip position and the course of the catheter using Fisher's exact test. Student's t-test or Mann–Whitney U test was used to compare the cranio-caudal spreading range of the radiocontrast agent, VAS scale, and total dose of morphine between groups (secondary outcomes). Baseline and perioperative characteristics of patients between groups were compared using the t-test or Mann–Whitney U test for continuous variables, and Fisher's exact test or the Chi-squared test for categorical variables.

Data were expressed as the mean ± SD, median [IQR] and number of samples (proportion). P values < 0.05 were considered to be statistically significant. All statistical analyses were performed using R software version 3.5.1 (The R Foundation for Statistical Computing, Vienna, Austria).

Results

The recruitment and enrolment of the patients are shown in a CONSORT flow diagram (Fig. 2). We randomly allocated 60 patients into the transverse (*n*=30) or parasagittal groups (*n*=30) between July 2015 and March 2016. All patients underwent ultrasound-guided TPVB and fluoroscopy. During thoracic surgery, the surgical procedure changed to thoracoscopic biopsy (due to inoperability) in two cases, and the catheter tip position was misplaced in the thoracic cavity and had to be subsequently changed to the TPVS in three cases. Therefore, 55 patients were analysed for postoperative analgesia as a secondary outcome: transverse (*n*=28) and parasagittal (*n*=27) groups. There were no significant differences in patient characteristics between groups (Table 1). There were no adverse events related to ultrasound-guided TPVB and the injection of a radio-contrast agent via the catheter reported in this study.

Catheter tip position, course of catheter, and spreading of radiocontrast

With respect to the primary outcome, the catheter tip was placed into the TPVS in 77% of patients in the transverse group (*n*=23) vs. 80% of patients in the parasagittal group (*n*=24) (*P*=1.00; Table 2). Displacement of the catheter outside of the TPVS was in back muscle (*n*=1), posterior mediastinum (*n*=3), or thoracic cavity (*n*=2) in the parasagittal group. In contrast, displacement was in back muscle (*n*=4), posterior mediastinum (*n*=2), or epidural space (*n*=1) in the transverse group. The course of the catheter was either coiled up or looped in 50% of patients in the transverse group vs. 60% of patients in the parasagittal group (*P*=0.60; Table 2).

With respect to the secondary outcome, spreading of the radiocontrast agent (mean ± SD vertebral segments) in the cranio-caudal direction was not significantly different between groups: 2.8 ± 1.0 vertebral segments in the transverse group vs. 2.7 ± 1.4 vertebral segments in the parasagittal group (*P*=0.75; Table 3).

Postoperative pain control

With respect to postoperative pain management, the median [IQR] postoperative VAS score at 24 h was 19.5 [12 to 25] mm at rest and 55 [44 to 77] mm on movement in the transverse group vs. 22 [12 to 33.5] mm at rest and 59 [41.5 to 75] mm on movement in the parasagittal group. These differences were not significantly different (*P*=0.57 at rest, *P*=0.76 on movement). Furthermore, the median morphine consumption in the first 24 h was 11.5 [5 to 21] mg in the transverse group vs. 11 [5 to 18] mg in the parasagittal group; these values were not significantly different (*P*=0.99; Table 4).

Discussion

To the best of our knowledge, this is the first study to evaluate the clinical effects of continuous ultrasound-guided TPVB between two different in-plane approaches: transverse vs. parasagittal. Although both in-plane approaches showed high rates of correct catheter placement into the TPVS, compared with the rates in past reports,[12-13] we found no significant differences in rates of correct catheter placement between the two in-plane approaches. Additionally, paravertebral cranio-caudal spreading and postoperative pain were not significantly different between the two approaches.

A previous human cadaver study using the parasagittal in-plane approach revealed the successful paravertebral spread of contrast agent in 11 of 20 human cadaver punctures (55%).[12] In contrast, the correct catheter placement into the TPVS was 60% using the transverse in-plane approach.[13] In our study, successful catheter placement was 77% and 80% in the transverse and parasagittal groups, respectively. Both approaches have improved the success rate of catheter placement into the TPVS compared with the previous reports.[12-13] This may be due to the use of an 8-5 MHz microconvex array transducer in our study. During the parasagittal in-plane approach, it is more difficult to restrict the needle motion using this microconvex probe when compared with the 10-5 MHz liner array transducer or 5-2 MHz convex array transducer, which have been reported previously.[12-13] In addition, this transducer allows the needle to penetrate the skin closer to the median line using the transverse in-plane approach. Therefore, regardless of the skin incision size and potential need for posterolateral thoracotomy, the paravertebral catheter is less affected by the surgical field.

Failure of thoracic epidural anaesthesia occurs in 13-32% of patients in clinical practice.[16] The present study showed that the failure of catheter placement into the TPVS occurred at a rate of approximately 20% in both approaches; this finding was similar to that in thoracic epidural anaesthesia. Past reports have demonstrated that the position of the paravertebral catheter was highly variable.[12-14] This study also suggested that it is difficult to accurately place the catheter into the TPVS for TPVB. In approximately half of the cases, the course of the catheter was not straight, but either coiled up or looped. The course of the catheter was not related to the needle tip position or approach direction. Moreover, Luyet et al. demonstrated the incidence of catheter placement in the thoracic cavity was 3-5%.[12, 14] This study also showed that catheter placement in the thoracic cavity was 2 cases (3%). We should not insert the needle deeper during TPVB because of the risk of penetrating the parietal pleura. The risk of penetrating the parietal pleura from the needle is higher using a parasagittal in-plane approach compared with the transverse in-plane approach because a Tuohy needle is used at a steep angle and the approach window is narrow between the bony structures in this approach. In contrast, the transverse in-plane approach is less likely to interfere with the Tuohy needle motion and ultrasound image from the bony structure.

In addition, Paraskeuopoulos et al. compared the paravertebral spread of single paravertebral needle injection between different in-plane techniques.[15] Consistent with our results regarding paravertebral block, they demonstrated that successful paravertebral spread of the dye occurred in 17 of 19 patients (89.5%) and 13 of 14 patients (92.8%) using ultrasound-guided transverse in-plane and parasagittal in-plane approaches, respectively. Although the current and past studies were not equality tests, these data indicate that both in-plane approaches may be effective in ultrasound-guided TPVB.

There were several limitations in this study. First, the sample size calculation may be inadequate. In this study, the sample size was calculated based on a previous study,[12] which showed accurate paravertebral spread in 55% of patients using the parasagittal in-plane approach. However, our study showed correct catheter placement in 80% of patients. This difference may be due to advances in the nerve block technique and ultrasonic transducers between the studies. Second, the paravertebral catheter was inserted at a depth of 4 cm into the TPVS, in accordance with our routine clinical practice and past reports.[12-13] Catheter tip position can vary depending on the depth of the paravertebral catheter; the optimal insertion distance for a paravertebral catheter remains unclear. Future studies are required to determine the optimal insertion distance of a paravertebral catheter. Third, this study did not compare clinical outcomes between other TPVB approaches, such as the out-of-plane approach. A previous study has reported various ultrasound-guided TPVB approaches.[4] The clinical effect of TPVB due to the difference between these approaches has not yet been elucidated. Further investigations are necessary to clarify the most effective TPVB approach.

Conclusion

This study demonstrated that both transverse and parasagittal in-plane approaches in TPVB using a microconvex ultrasound probe allowed correct catheter placement into the TPVS in 80% of patients. However, there was no significant difference between two in-plane approaches for correct catheter placement into the TPVS, cranio-caudal spreading of the radiocontrast agent, and postoperative pain. These data suggest that both in-plane TPVB techniques are equally effective when using a microconvex ultrasound probe. The choice between either a transverse in-plane or parasagittal in-plane approach is largely determined by the patient’s physique, the surgeon’s experience, performance, or surgical situation.

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References

1. Eason MJ, Wyatt R. Paravertebral thoracic block-a reappraisal. *Anaesthesia* 1979; **34**:638-642.

2. Karmakar MK. Thoracic paravertebral block. *Anesthesiology* 2001; **95**:771-780.

3. Richardson J, Lönnqvist PA. Thoracic paravertebral block. *Br J Anaesth* 1998; **81**;230-238.

4. Krediet AC, Moayeri N, van Geffen GJ, et al. Different approaches to ultrasound-guided thoracic paravertebral block: an illustrated review. *Anesthesiology* 2015; **123**:459-474.

5. D'Ercole F, Arora H, Kumar PA. Paravertebral block for thoracic surgery. *J Cardiothorac Vasc Anesth* 2018; **32**:915-927.

6. Karmakar MK. Ultrasound-guided thoracic paravertebral block. *Techniques in Regional Anesthesia and Pain Management* 2009; **13**:142-149.

7. Hara K, Sakura S, Nomura T, Saito Y. Ultrasound guided thoracic paravertebral block in breast surgery. *Anaesthesia* 2009; **64**:223-225.

8. Shibata Y, Nishiwaki K. Ultrasound-guided intercostal approach to thoracic paravertebral block. *Anesth Analg* 2009; **109**:996-997.

9. Ben-Ari A, Moreno M, Chelly JE, Bigeleisen PE. Ultrasound-guided paravertebral block using an intercostal approach. *Anesth Analg* 2009; **109**:1691-1694.

10. O Riain SC, Donnell BO, Cuffe T, Harmon DC, Fraher JP, Shorten G. Thoracic paravertebral block using real-time ultrasound guidance. *Anesth Analg* 2010; **110**:248-251.

11. Abdallah FW, Brull R. Off side! A simple modification to the parasagittal in-plane approach for paravertebral block. *Reg Anesth Pain Med* 2014; **39**:240-242.

12. Luyet C, Eichenberger U, Greif R, Vogt A, Szücs Farkas Z, Moriggl B. Ultrasound-guided paravertebral puncture and placement of catheters in human cadavers: an imaging study. *Br J Anaesth* 2009; **102**:534-539.

13. Cowie B, McGlade D, Ivanusic J, Barrington MJ. Ultrasound-guided thoracic paravertebral blockade: a cadaveric study. *Anesth Analg* 2010; **110**:1735-1739.

14. Luyet C, Herrmann G, Ross S, et al. Ultrasound-guided thoracic paravertebral puncture and placement of catheters in human cadavers: where do catheters go? *Br J Anaesth* 2011; **106**:246-254.

15. Paraskeuopoulos T, Saranteas T, Kouladouros K, et al. Thoracic paravertebral spread using two different ultrasound-guided intercostal injection techniques in human cadavers. *Clin Anat* 2010; **23**:840-847.

16. Hermanides J, Hollmann MW, Stevens MF, Lirk P. Failed epidural: causes and management. *Br J Anaesth* 2012; **109**: 144-154.

Tables and Figures

Table 1

Baseline and perioperative characteristics

	Transverse group (*n*=30)	**Parasagittal group (*n*=30)**
Age (years)	66.6 ±10.0	66.1±8.6
Sex (Female)	10 (33%)	8 (27%)
BMI (kg m^{-2})	21.5±3.2	22.0±2.8
ASA-PS (class 1 / 2)	7 / 23	7 / 23
Operation (Lobectomy / Segmentectomy)	22 / 5	22 / 3
Length of skin incision (mm)	154±52	150 ±53
Operation Time (min)	167.3±57.4	165.4±70.6
Anaesthesia Time (min)	264.2±62.5	262.9±71.2
In-Out Balance (ml)	660.2±186.4	613.5±215.8
Intraoperative ropivacaine dose (mg)	190.7±23.2	188.0±26.1

Values are mean ± SD or number (proportion). BMI, body mass index; ASA-PS, American Society of Anesthesiologists physical status.

Table 2

Comparison of the catheter tip position (primary outcome) and the course of catheter

	Transverse group (*n*=30)	Parasagittal group (*n*=30)	*P* value
Catheter tip position			
Paravertebral space	23 (77%)	24 (80%)	1.00
Other spaces	7 (23%)	6 (20%)	
Odds ratio (95% CI)	0.82 (0.20 to 3.36)		
(breakdown of other spaces)	1	0	
Epidural space	4	1	
Back muscle	0	2	
Thoracic cavity	2	3	
Posterior mediastinum			
Course of catheter			
coiled up or looped	15 (50%)	18 (60%)	0.60

Values are number (proportion) of patients.

Table 3

Comparison of cranio-caudal spreading range of radiocontrast (secondary outcome)

Spreading to cranio-caudal direction	**Transverse group (*n*=30)**	**Parasagittal group (*n*=30)**	***P* value**
Cranio-caudal direction ; vertebral segments	2.8±1.0	2.7±1.4	0.75
caudal side	1.1±0.6	0.9±0.5	0.28
cranial side	1.7±0.8	1.8±1.0	0.78

Values are mean ± SD of vertebral segments.

Table 4

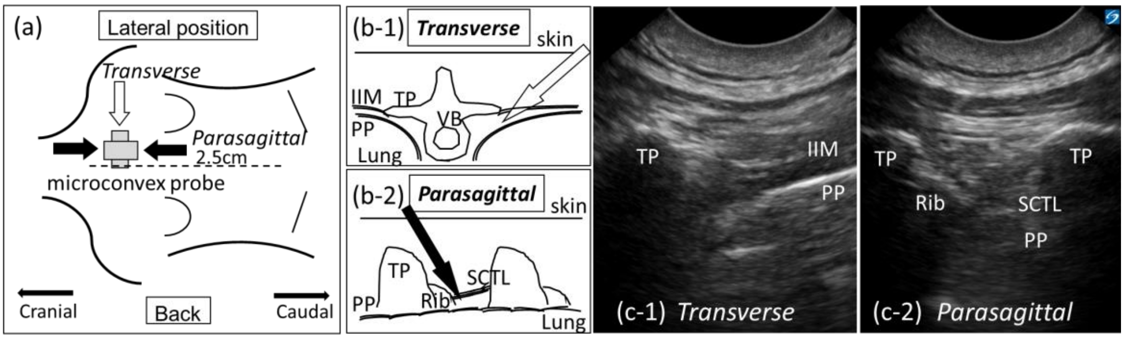
Comparison of postoperative pain condition in the first 24 h (secondary outcome)

Postoperative pain condition	**Transverse group (*n*=28)**	**Parasagittal group (*n*=27)**	***P* value**
VAS score at rest (mm)	19.5 [12 to 25]	22 [12 to 33.5]	0.57
VAS score on movement (mm)	55 [44 to 77]	59 [41.5 to 75]	0.76
Morphine consumption (mg)	11.5 [5 to 21]	11 [5 to 18]	0.99

Values are median [IQR]. VAS, visual analogue scale.

Fig. 1

Two different in-plane approaches of ultrasound-guided thoracic paravertebral block



(a) The patient is positioned in a lateral decubitus position with the surgical site on the upper surface. In the transverse group, a microconvex probe is placed transversely between adjacent ribs and visualised using the transverse ultrasound view (b-1 and c-1). In the parasagittal group, a microconvex probe is placed sagittally at approximately 2.5 cm lateral to the midline between the adjacent transverse processes and visualised using the parasagittal ultrasound view (b-2 and c-2). A Tuohy needle is inserted in a lateral-to-medial direction at 4 cm away from the midline (b-1), or cranial-to-caudal or caudal-to-cranial direction at 2.5 cm away from the midline (b-2) from the outer edge of the transducer and advanced until the needle tip was positioned in the lateral edge of the thoracic paravertebral space. TP, transverse process; IIM, internal intercostal membrane; SCTL, superior costotransverse ligament; PP, parietal pleura; VB, vertebral body.

Fig. 2

CONSORT flow diagram