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ORIGINAL ARTICLE

Ultrasound-guided continuous thoracic paravertebral block provides comparable analgesia and fewer episodes of hypotension than continuous epidural block after lung surgery

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Abstract
Purpose Both paravertebral block (PVB) and thoracic epidural block (TEB) are recommended for postoperative pain relief after lung surgery. The addition of fentanyl to the anesthetic solution became popular for TEB because of the stronger effects; however, there have been few comparable trials about the addition of fentanyl to PVB. The purpose of this study was thus to compare postoperative analgesia, side effects, and complications between ultrasound-guided PVB (USG-PVB) and TEB with the addition of fentanyl to ropivacaine after lung surgery.
Methods We examined 90 consecutive patients (age 18–75 years) scheduled for video-assisted thoracic surgery (VATS). In both groups, all blocks (four blocks in USG-PVB and one block in TEB) and one catheter insertion were performed preoperatively. Continuous postoperative infusion (0.1 % ropivacaine plus fentanyl at 0.4 mg/day) was undertaken for 36 h in both groups. The recorded data included the verbal rating scale (VRS) for pain, blood pressure, side effects, complications for 2 days, and overall satisfaction score.
Results There was no difference in the frequency of taking supplemental analgesics (twice or more frequently), or in VRS. Hypotension occurred significantly more frequently in TEB ($n = 7/33$) than in PVB ($n = 1/36$) ($P = 0.02$); on the other hand, the incidences of PONV and pruritus, as well as overall satisfaction score, were similar. There were no complications in both groups; however, the catheters migrated intrathoracically in four patients in PVB.
Conclusion USG-PVB achieved similar pain relief and lowered the incidence of hypotension compared with TEB. We conclude that both blocks with the same concentration of ropivacaine and fentanyl can provide adequate postoperative analgesia for VATS.

Keywords Ultrasound guidance · Thoracic paravertebral block · Epidural block · Postoperative analgesia · Lung surgery

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Introduction

Continuous thoracic epidural block (TEB) and continuous paravertebral block (PVB) have been established as primary analgesic approaches for pain control after thoracotomy. PVB was reported to provide comparable analgesia to TEB with fewer side effects, such as postoperative nausea and vomiting (PONV), hypotension and urinary retention, and fewer pulmonary complications, in a review article [1]. However, the authors stated that PVB was evaluated not to be superior to TEB in terms of biases, such as various kinds of regimen, unclear optimal doses, different placements of PVBs, and different endpoints, in previous comparable trials of the two methods, and that further trials were required [1, 2]. In general, the addition of fentanyl to TEB is considered to improve the analgesic effect qualitatively compared with an increased dose of local anesthetics (LA) or IV morphine [3]; therefore, this method has been universally used.

On the other hand, few studies have examined the effects of adding fentanyl to PVB in comparison with other nerve blocks [4].

Hence, this prospective, randomized study was designed to compare postoperative analgesia, side effects, and complications between ultrasound-guided PVB (USG-PVB) and TEB using 0.1 % ropivacaine and fentanyl (0.4 mg/day) after video-assisted thoracic surgery (VATS). We hypothesized that USG-PVB would provide stronger pain relief (primary outcome) with fewer side effects (secondary outcome) than TEB.

Methods

After obtaining approval from the local ethics committee of our hospital and informed consent from the patients, we examined 90 consecutive patients (age: 18–75 years) with ASA physical status I–III scheduled for VATS with an axillary skin incision of 6–8 cm at Nishi-Kobe Medical Center in Kobe, Japan, between August 2008 and October 2009. When the type of elective surgery was altered or extended beyond thoracotomy, the patient was withdrawn from this study. The exclusion criteria were as follows: allergy to non-steroidal anti-inflammatory drugs (NSAIDs) or LA, renal or hepatic failure, body mass index over 30 kg/m^2, infection at injection site, coagulative abnormality, and inability to comprehend pain scoring. The patients were assigned randomly into two groups using the sealed envelope technique. Group P received USG-PVB and group E received TEB. Both blocks were performed preoperatively and the methods were as follows.

In group P, after placing the patient in the lateral decubitus position, the attending anesthesiologist discerned the puncture site with a linear 4–10 MHz ultrasound probe (LOGIQe, GE Healthcare, Waukesha, WI) as follows: after distinguishing the targeted transverse process (TP) from the junction of the ribs on the horizontal plane, the cranial end of the TP was marked on the skin as the puncture site on the sagittal plane. After standard skin disinfection, a 17G Tuohy needle (Arrow International, Reading, PA) was inserted perpendicularly or slightly caudally into the paravertebral space (PVS) by the conventional loss-of-resistance technique (LOR), while the probe in a sterile cover was positioned facing the needle (in the sagittal plane) by another anesthesiologist (Fig. 1a). After the needle tip penetrated through the superior costotransverse ligament (SCTL), it was identified on the ultrasound image with a small dose of saline infused through the needle (Fig. 1b) and by LOR. We performed three single blocks with 5 ml of 0.5 % ropivacaine each at (1) the TP of second thoracic

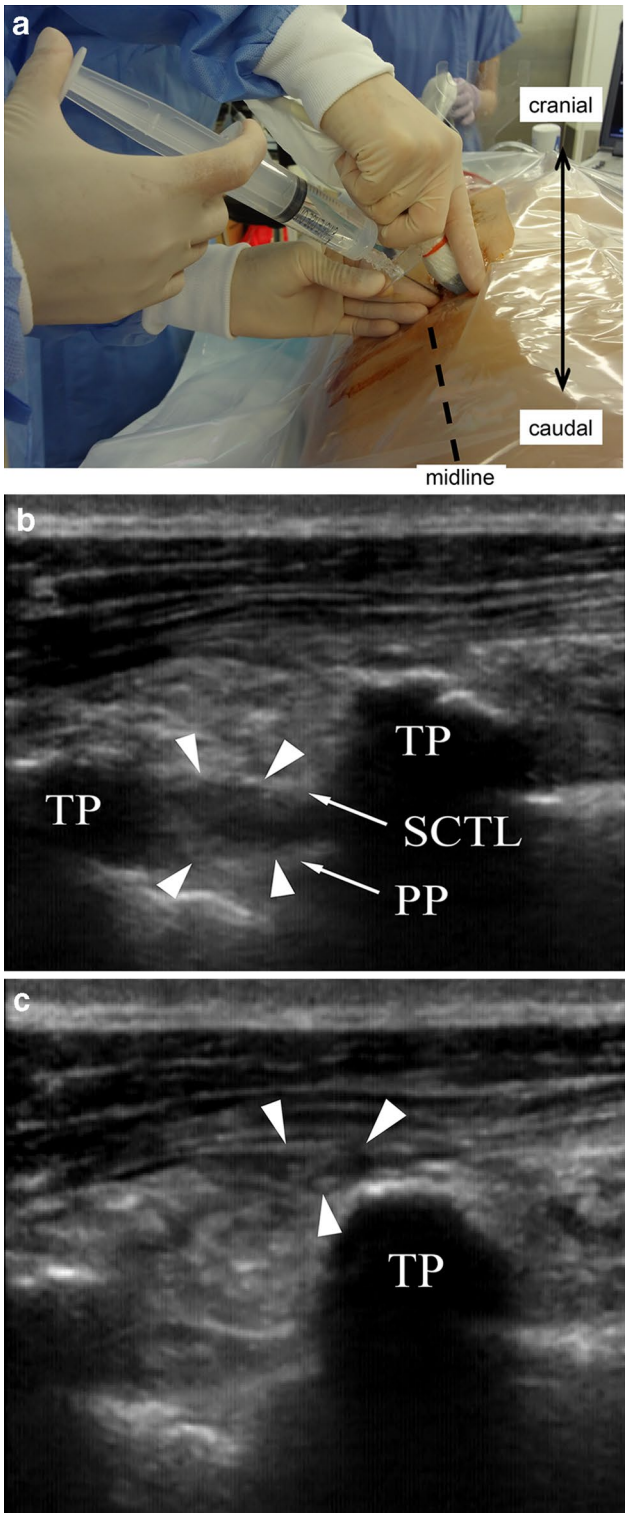

Fig. 1 **a** The probe facing the needle. **b** An ultrasonogram of the paravertebral space after local anesthetic infusion. **c** An ultrasonogram of inadequate saline infusion at the dorsum of the transverse process by the conventional loss-of-resistance method. *TP* transverse process, *PP* parietal pleural, *SCTL* superior costotransverse ligament

vertebra (TV), (2) the TP of sixth TV, corresponding to the site of the drainage tube, and (3) the TP of eighth TV. For catheter insertion, 15 ml of 0.5 % ropivacaine was injected through the needle at the site corresponding to the thoracotomy incision (the TP of fourth TV), and a 20G catheter (Flex Tip® Catheter, Arrow International, Reading, PA) was inserted up to 4 cm from the needle tip.

In group E, after placing the patient in the lateral decubitus position and carrying out standard skin disinfection, 1 % lidocaine was injected into the skin at the targeted intervertebral space corresponding to the thoracotomy incision. After a 17G Tuohy needle was inserted into epidural space by the LOR technique with saline, a 20G catheter (Flex Tip® Catheter, Arrow International, Reading, PA) was inserted up to 4 cm from the needle tip through the needle. An epidural bolus dose (5–7 ml) of 0.25–0.375 % ropivacaine was administered before skin incision.

All patients received standardized general anesthesia with standard monitoring. Anesthesia was induced with intravenous fentanyl at 50 μg and propofol (target controlled infusion (TCI) at 5 μg/ml), and maintained with intravenous propofol (using a BIS monitor for an index of 40–60). Double-lumen, endobronchial intubation was facilitated with vecuronium bromide. Prophylactic antiemetics were not administered. During surgery, if necessary, 3–5 ml of 0.25–0.5 % ropivacaine was administered through a catheter, or secondary intravenous fentanyl (50 μg) was administered, at the attending anesthesiologist's discretion, whenever the manifestations of inadequate analgesia were noted. Before skin closure, continuous infusion was started for 36 h in all patients. In group P, the analgesic solution, the volume of which was 220 ml [225 mg of ropivacaine (0.1 % ropivacaine) and 0.6 mg of fentanyl (0.4 mg/day)], was infused at a rate of 6 ml/h. In group E, the two types of analgesic solution were infused: when the body weight was more than or less than 65 kg, a rate of 4 ml/h or 2 ml/h was used, respectively. A total of 150 ml of the solution was infused at 4 ml/h, in which 150 mg of ropivacaine (0.1 % ropivacaine) and 0.6 mg fentanyl (0.4 mg/day) were included. The remaining solution of 75 ml was infused at 2 ml/h, in which 75 mg of ropivacaine (0.1 % ropivacaine) and 0.6 mg of fentanyl (0.4 mg/day) were included. After surgery, the catheter placements were examined by X-ray and the positions of the catheter tips were recorded. The patients were then extubated and transferred to the intensive care unit (ICU). We recorded the anesthesia time, operation time, amount of fluid administration, and usage of fentanyl and ropivacaine.

The data were recorded on ICU admission, at 1, 3, 6, 12, and 24 h, and on the second postoperative day (POD2). The data included the verbal rating scale for pain at rest (VRS; 0 = none, 10 = maximum pain), blood pressure, side effects such as PONV and pruritus, and postoperative lung complications. Loxoprofen sodium (60 mg) was given orally three times a day after POD1. NSAIDs (IV flurbiprofen: 50 mg on the day of operation or diclofenac sodium suppository: 50 mg after POD1) and pentazocine (15 mg intramuscularly) were given on demand for moderate pain. When the patients suffered from severe pain despite this protocol for analgesia, intravenous fentanyl was administered and then those patients were withdrawn from this study. All patients were administered Ringer's solution at a rate of 80 ml/h postoperatively until POD1, and then shifted to oral intake. Side effects, defined as hypotension (systolic blood pressure less than 90 mmHg), PONV, or pruritus, were recorded. Despite rapid hydration with 500 ml of Ringer's solution or IV administration of 10 mg of metoclopramide, if the side effects persisted, the continuous infusion for blocks was stopped. The overall satisfaction score for pain relief (1 = dissatisfied, 5 = satisfied) was written on paper anonymously, placed in an envelope, and collected by the attending anesthesiologist after completion of the continuous infusion.

Almost 50 % of the patients receiving epidural block (ropivacaine/fentanyl) in our hospital usually took supplemental analgesics more than twice over the first 48 h postoperatively. A sample size of 30 in each group was calculated by estimating a significant reduction of the number of patients using supplemental analgesics as less than 20 % in the PVB group, with $\alpha = 0.05$ and $\beta = 0.8$. Given our experience, we recruited 45 patients in each group because of the high incidence of alteration of surgery type in our hospital.

The data were analyzed using Statview 5.0 (SAS Institute Inc., Cary, NC). All quantitative parametric values are presented as mean ± SD, while the other non-parametric values are presented as median (interquartile range). Independent Student's *t*-test, Mann–Whitney *U* test, chi-square test, and Fisher's exact test were used as appropriate. The null hypothesis was rejected when *P* was less than 0.05.

Results

In total, 36 patients in group P and 33 patients in group E completed this study and were examined, while the others were withdrawn (Fig. 2). The patients' characteristics did not differ between the two groups (Table 1). In group P, ropivacaine was confirmed in all PVSs on the ultrasound imaging; however, in some of them, the catheters could not be inserted smoothly. Four patients (8.9 %) among them were withdrawn from this study because the catheters migrated into the intrathoracic space, being defined as failed insertion. In group E, one patient was excluded because of the development of a large hematoma in the skin.

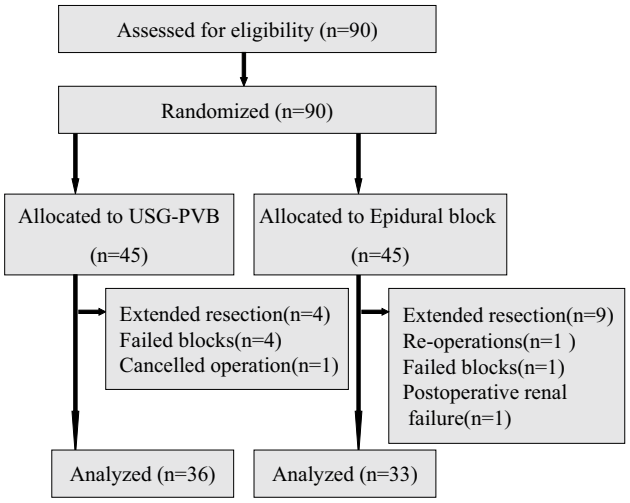

Fig. 2 Flow diagram of patients. Extended resection means that patients needed other organ resection. Failed block means that the catheter could not be inserted by each protocol method

Table 1 The patients' characteristics

	Group E	Group P
n	33	36
Sex	M/F 24/9	M/F 20/16
Age[a]	63.0 ± 11.1	61.0 ± 15.9
Weight[a] (kg)	61.0 ± 10.0	59.5 ± 9.5
Height[a] (cm)	165.0 ± 8.4	165.5 ± 9.8
Types of surgery		
Lobectomy	15	11
Segmentectomy	2	2
Wedge resection	16	23

M male, *F* female

[a] Mean ± SD

Table 2 Incidence of side effects

	Group E	Group P	*P* value
Hypotension	7/33	1/36	0.02
PONV	10/33	9/36	0.62
Pruritus	1/33	0/36	0.29
Supplemental analgesia[a]	1.0 [0.0–3.0]	2.0 [1.0–3.9]	0.26
Overall satisfaction score	5.0 [3.0–5.0]	4.5 [3.0–5.0]	0.26

[a] The frequency of supplemental analgesia

Pain relief

The frequencies of taking supplemental analgesics were similar in the two groups (Table 2). The proportions of patients using supplemental analgesics more than twice were 56 % in group P and 48 % in group E. There were no significant differences in VRS between group P and group E at any time (Fig. 3). In both groups, the median values were always less than 4 at all times. No patient required intravenous fentanyl in either group.

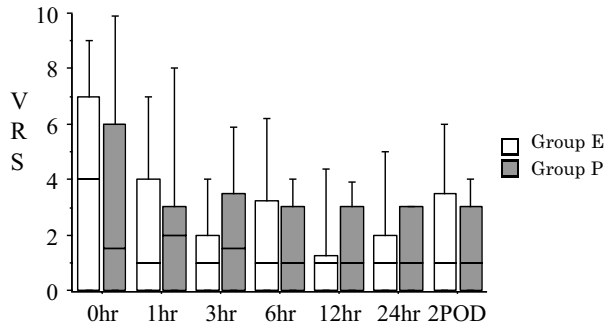

Fig. 3 The verbal rating scales were recorded at 0, 1, 3, 6, 12, and 24 h, and on the second postoperative day (POD2). No statistically significant differences were noted between the two groups at each time point. *Box* 25th–75th percentiles, *solid line* median, *extended bars* 10th–90th percentiles

Side effects

Hypotension occurred significantly more frequently in group E ($P = 0.0169$), while no statistically significant differences were noted with respect to PONV and pruritus (Table 2).

Others

There were no significant differences in operation time (group P 126 ± 78.7 min, group E 159 ± 84.3 min, $P = 0.53$) or in anesthesia time (group P 203 ± 84.2 min, group E 213 ± 91.1 min, $P = 0.79$). There were no neurological complications in either group. The amounts of intraoperative fluid were similar at 700 ± 247 ml in group P and 650 ± 245 ml in group E ($P = 0.23$). The uses of intraoperative fentanyl were comparable in the two groups (group P 100 ± 55 μg, group E 100 ± 60 μg, $P = 0.11$); meanwhile, ropivacaine was infused more in group P (110 ± 31 mg) than in group E (49 ± 26 mg, $P < 0.0001$). The catheter insertions according to the skin incision segments were at Th 4 [3, 4] in group P and Th 5 [3–5] in group E, with no difference between the targeted ideal site and the actual insertion site in either group. The postoperative consumptions of fentanyl were equivalent in the two groups (0.6 ± 0.14 mg in group P, 0.6 ± 0.16 mg in group E, $P = 0.22$). However, the postoperative administration of ropivacaine in group P was more than that in group E (194.6 ± 53.3 mg in group P, 79.9 ± 44.2 mg in group E, $P < 0.0001$).

Discussion

In this study, USG-PVB was shown to have a similar pain-relieving effect to TEB, with a lower incidence of postoperative hypotension; it did not decrease the number of patients using complementary analgesics twice or more frequently and showed no significant differences in VRS. Davies et al. [1] analyzed the results of 10 trials, and concluded that PVB provides a similar analgesic effect to TEB, with fewer side effects (respiratory complications, urinary retention, PONV, and hypotension), when PVB was used after pulmonary resection, in their review article. On the other hand, it should be noted that the results, particularly the disadvantages, varied slightly among the trials due to the different solutions in analgesic regimens for both blocks. There were a few trials which compared PVB and TEB, using ropivacaine and fentanyl in both blocks. PVB (LA only) provided similar pain relief and reduced the incidence of postoperative hypotension compared with TEB (LA only) [5] or TEB (LA with/without opioids) [1], which is in accordance with the results of the present study. In PVB, a larger amount of ropivacaine was used than in TEB both intra- and postoperatively, while the incidence of hypotension and hemodynamic changes decreased as a result of unilateral sympathetic blockage. The required amount of analgesic solution to obtain appropriate pain-relieving effects in each block could differ simply due to the size of the anatomical space. It is desirable to prevent severe hypotension related to excessive volume overload, particularly after pulmonary resection, even if there was no difference between the two groups in terms of the quantity of solution infused throughout the postoperative period in this trial.

The similar incidences of PONV in the 2 groups are inconsistent with the results of previous studies using PVB (LA only), which caused PONV less frequently than TEB (LA with/without opioids) [PVB: 10 % (10/100); TEB: 20.2 % (21/104)] [1]; this may be explained by the additional fentanyl, similarly administered in both groups. Bimston et al. [6] reported that a high PONV incidence was observed in both blocks with similar fentanyl infusions (PVB: 23.3 %; TEB: 35 %) after lung surgery, supporting the results of the present study. It was confirmed that there were no differences in the changes of plasma concentrations after fentanyl infusion between PVB and TEB [6] or between TEB and IV [7, 8]. With regard to continuous fentanyl infusion into epidural space, fentanyl predominantly acts at supraspinal sites, while boluses of fentanyl produce segmental analgesia through spinal opioid receptor activity [9, 10]. In short, in both blocks, fentanyl may have been immediately absorbed in the circulatory system after administration, and, in the presence of the supraspinal opioid receptor, may have generated analgesic effects, while inducing PONV. The high incidences of PONV in both blocks observed in the present study may be explained by this mechanism. On the other hand, LA, which was administered to PVS by Moore's method, medially expanded into the epidural space through the intervertebral foramen, providing only unilateral analgesic effects in 70 % of cases [11]. At present, there are no reports confirming that PVB fentanyl clearly has an analgesic effect on spinal opioid receptors, whether administered as a bolus or continuously.

Although the dose of fentanyl was reduced to 0.4 mg/day in consideration of the dose of 0.6 mg/day used in a previous study [6], the incidence of PONV remained high, suggesting the appropriateness of titrating fentanyl doses in VATS. It is necessary to examine further the advantages (providing stronger analgesia) and disadvantages (involving opioid-related side effects) of PVB combined with fentanyl at various doses.

In four patients (8.9 %), their catheters were displaced intrathoracically. In these cases, LA infusion pressing down on the parietal pleura was verified both on an ultrasound image and under direct vision, but only the tips of the catheters penetrated the pleura intrathoracically. In human cadaveric studies, it was reported that, after easy puncture to PVS, catheter insertion was difficult in 30–50 % of cases and catheter migration occurred in 40–45 % of cases, as shown in this study [12, 13]. When it was difficult to insert a catheter, we rotated a Tuohy needle in another direction without ultrasound assistance. According to this experience, we re-attempted needle insertion or turned the needle close to SCTL in this situation after this trial. Unlike past classic approaches, ultrasound guidance in the present study had a benefit of preventing inappropriate intrafascial injections at sites other than PVS owing to sudden pressure changes [14] (Fig. 1c).

This study has some limitations. First, intraoperative fentanyl consumption decided by an anesthesiologist might have influenced the postoperative course. However, there was no difference in the amounts of fentanyl between the two groups. Second, the infusion rate of 2–4 ml/h in TEB could have influenced the results. The rates were clearly less than the value of 0.1 ml/kg/h in previous reports, although the ideal infusion rate was not established [3, 6]. In TEB, fentanyl added to ropivacaine could decrease the ropivacaine concentration, providing similar analgesia post-thoracotomy [3]. The low rate of infusion for patients undergoing VATS with minimal invasion in particular had been acceptable in our facility with low VRSs, similar to that in other reports. Two different fixed infusion rates of ropivacaine in TEB and one fixed rate of fentanyl in all patients might have affected pain scores and disadvantages; however, dynamic variable systems in analgesic solutions could have led to better results. Furthermore, in the present study, sufficient data regarding pain relief upon movement

and information about the area for effective analgesia were lacking; although they are associated with earlier recovery postoperatively and from other uncomfortable conditions. Therefore, further studies should be undertaken to examine the relationship between the dose of analgesics and areas for effective analgesia.

In conclusion, USG-PVB provided similar postoperative analgesia to TEB for patients undergoing VATS. PVB had better advantages in terms of the maintenance of hemodynamics and the prevention of hypotension. On the other hand, PVB combined with fentanyl caused a high incidence of PONV, similarly to TEB, so further trials are required to search for an adequate dosage. We conclude that USG-PVB and TEB are similarly acceptable for postoperative analgesia after VATS.

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