Intraoperative changes in upper extremity perfusion index after thoracic paravertebral and intertransverse process block in patients undergoing lung resection surgery

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Background: Perfusion index (PI) has been used as a surrogate marker of sympathetic blockade. This study evaluated changes in PI of bilateral upper extremity after thoracic paravertebral block (PVB) and intertransverse process block (ITPB).

Methods: This pilot study included three groups of patients undergoing elective unilateral pulmonary resection under general anesthesia with PVB (n=11) or ITPB (n=10), or urologic procedures with general anesthesia (control group, n=10). Blockades were performed using 10 mL aliquots of 0.5% ropivacaine administered at T3–4, T5–6, and T7–8 intercostal levels immediately after general anesthesia induction. The PI value of the operating side (PI-O) was divided by the contralateral side (PI-CL), and the relative change to baseline was assessed (relative PI-O/PI-CL), with a 50% increase considered meaningful.

Results: In all cases within the PVB and ITPB groups, a significant increase in PI was observed following the blockades. The median (1Q, 3Q) intraoperative relative PI-O/PI-CL values were 0.9 (0.8, 1.4), 2.1 (1.4, 2.5), and 1.4 (0.9, 1.9) in the control, PVB, and ITPB groups (P=0.01), respectively. Pairwise comparison revealed a significant difference only between the control and PVB groups (adjusted P=0.01). While the relative PI-O/PI-CL value in the control group generally remained close to 1, occasional fluctuations exceeding 1.5 were noted.

Conclusions: PVB induced a noticeable unilateral increase in upper extremity PI, whereas ITPB tended to result in an inconsistent and lesser degree of increase. Monitoring PI values can serve as an indicator of upper extremity sympathetic blockade, but consideration of potential confounders impacting these observations during surgery is essential. Further research is needed to validate these findings.

Keywords: Perfusion index (PI); paravertebral block (PVB); intertransverse process block (ITPB); sympathetic block; sympathectomy

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Introduction

There has been an enthusiasm around paraspinal blocks (1-5). These blocks include erector spinae plane block, intertransverse process block (ITPB), and retrolaminar block, and commonly aims paravertebral spreading of local anesthetic without directly introducing the needle into the paravertebral space (6). This kind of approaches can relieve technical difficulty and decrease risks associated with the paravertebral block (PVB).

Previous cadaveric studies have demonstrated the spread of dye into the paravertebral space following paraspinal blocks (7-9). However, despite these findings, there is a lack of clinical data on the efficacy of these blocks in achieving sympathetic blockade. It is important to consider that cadaveric studies may have limitations and may not accurately reflect results in living patients (10,11). This highlights the need for a clinically feasible tool to evaluate sympathetic blockade.

Perfusion index (PI) is a parameter that derived from a photoplethysmogram signal and reflects the pulsatile versus non-pulsatile component of the signal. This index has been used as a surrogate marker of sympathetic blockade (12-16). This pilot study hypothesized that thoracic PVB and ITPB would increase PI of upper extremity. The aims of this study were two-fold: (I) to evaluate intraoperative changes in PI after these blockades; (II) to set up a framework for the analysis of intraoperative PI changes after these blockades. We present this article in accordance with the TREND reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-69/rc).

Highlight box

Key findings
- Paravertebral block induced a noticeable unilateral increase in upper extremity perfusion index (PI), whereas intertransverse process block tended to result in an inconsistent and lesser degree of increase.

What is known and what is new?
- PI has been used as a surrogate marker of sympathetic blockade.
- By monitoring bilateral upper extremity PI, sympathetic blockade can be observed intraoperatively.

What is the implication, and what should change now?
- Monitoring PI values can serve as an indicator of upper extremity sympathetic blockade, but consideration of potential confounders impacting these observations during surgery is essential.

Methods

This was a joined work of two pilot studies, one for (I) PVB; and the other for (II) ITPB, both conducted at a university affiliated hospital (Chungnam National University Hospital, Daejeon, Korea) from (i) November 2022 to January 2023; and (ii) June to August 2023. The study followed the Good Clinical Practice guidelines and the principles of the Declaration of Helsinki (as revised in 2013). The protocol was approved by the Institutional Review Board of Chungnam National University Hospital (1, CNUH 2022-07-078; 2, CNUH 2023-04-042) and was registered prior to patient enrollment at cris.nih.go.kr (1, KCT0007668; 2, KCT0008508). Written informed consent was obtained from all enrolled participants before surgery.

Participants

These studies commonly included patients aged 20 to 80 years, American Society of Anesthesiologist (ASA) physical status classification 1 to 3, body mass index (BMI) >18.5 and <35 kg/m^2 scheduled for elective unilateral pulmonary resection under general anesthesia with PVB or ITPB (study groups), or urologic procedure performed with general anesthesia (control group). Only the procedures that are planned to be performed under lateral decubitus position were included. The exclusion criteria included known hypersensitivity to the local anesthetics used in the study; pre-existing wound infection or severe inflammation; pre-existing non-minor pleural adhesion; pregnancy; previous intrathoracic surgery; limitation in the application of pulse oximeter monitoring in both hands (2nd or 3rd finger); known pathology that can manifest abnormal PI in upper extremity (e.g., arteriovenous fistula).

Design

The first pilot study (PVB) was designed as a two-arm non-randomized controlled trial. The study group was set to observe PI change after PVB intraoperatively. As the surgical position, lateral decubitus position, *per se* could affect the PI values in both hands, a control group was set which also adopts same surgical position intraoperatively. To meet the needs for a control group that matches the surgical position and anesthesia type of the study group, urologic procedures such as nephrectomy, radiofrequency ablation of renal mass were included.

The second pilot study (ITPB) was designed as a single

arm observational study which resembles the PVB group of the prior pilot study.

Anesthesia and monitoring

Anesthesia was conducted according to a standardized institutional protocol, involving 1.5–2 mg/kg of propofol, 0.6–1 mg/kg of rocuronium, and 1–1.5 µg/kg of remifentanil for induction. Maintenance included sevoflurane or desflurane inhalation alongside a continuous infusion of remifentanil at 0.05–0.2 µg/kg/min. Inhalation agents were adjusted based on processed electroencephalogram, while remifentanil dosage was modulated to maintain blood pressure and heart rate within ±25% of baseline values. Intraoperative mechanical ventilation was set at 6–8 mL/kg of tidal volume, 0.4–1.0 of inspired oxygen fraction, with respiratory rate adjustments aimed at maintaining end-tidal carbon dioxide levels within 35–45 mmHg.

In addition to the standard ASA monitoring, disposable pulse oximeter sensors (RD rainbow SET™-2 Neo sensor, Masimo Corp., Irvine, CA, USA) were applied to both hands (2nd or 3rd finger) and monitored distinctively via corresponding monitors. The PI values were continuously recorded at 1 Hz of frequency via a free data collection program (Vital recorder version 1.10, accessed at https://vitaldb.net, Seoul, Republic of Korea) (17).

Interventions

Following the induction of general anesthesia and the placement of a central venous line as required, blockades were conducted with the patient positioned laterally. A 22-gauge, 80 mm echogenic needle (SonoPlex Stim, Pajunk, Geisingen, Germany) was utilized along with either of two ultrasound machines (Venue Go R2, GE Healthcare, Wauwatosa, WI, USA; SonoSite SII, FUJIFILM, Bothell, WA, USA) and corresponding high-frequency linear probes. These procedures were carried out by anesthesiologists proficient in ultrasound-guided regional techniques.

PVB was performed using an in-plane transverse approach, as previously described (18). Once an optimal image was obtained, consisting of the transverse process, wedge-shaped hypoechoic paravertebral space, and parietal pleura, the needle was advanced from lateral to medial until the tip penetrated the internal intercostal membrane. Proper needle placement was confirmed by observing the downward displacement of the pleura during the injection of local anesthetic; 10 mL aliquots of 0.5% ropivacaine

were administered at the T3–4, T5–6, and T7–8 intercostal levels, starting from the upper to lower levels. A protocol update was implemented on December 16, 2022, after enrolling four subjects in the control group. This update shifted from a dual injection protocol (T4–5 and T6–7) to the triple injection protocol previously described, in response to a request from the surgical department to encompass a wider range of dermatomes. This protocol change occurred after enrolling subjects in the control group, ensuring no variations in the protocol within the study groups.

ITPB was conducted using an out-of-plane approach targeting mid-point transverse process above superior costotransverse ligament (5). Proper needle placement was confirmed by observing slight bulging of the intertransverse connective tissue complex during injection; 10 mL aliquots of 0.5% ropivacaine was administered at the same intercostal levels and the sequence as the PVB.

Measurements

The primary measurement was the PI values in both hands. As the procedures were performed with lateral decubitus position, the hand of the operating side (nondependent) was placed on an arm board adjusted for the surgical exposure. To assess the impact of changes in position and blockade on PI, each time point of the events (i.e., immediately after the position change and completion of the blockades) was recorded.

Since the PI values were obtained intraoperatively rather than resting state, confounding due to general anesthesia and positioning was expected. To adjust such factors, the PI value of the operating side (PI-O) was divided by the value of contralateral side (PI-CL). Then the relative change to the baseline (during the initial 3 minutes after position change) was assessed (relative PI-O/PI-CL). A previous study reported a factor of 1.55 times baseline PI value as a sensitive and specific marker for the successful regional block (13). Based on this, a 50% increase in the adjusted value (i.e., 1.5 of relative PI-O/PI-CL) was considered a meaningful increase. A list of the processed measurements is presented in *Table 1*.

In the main analysis, PI values obtained during the observation period up to one hour after the position change were used, taking into consideration the case-specific variations in the observation period. To avoid any errors from the cuff inflation during noninvasive blood pressure measurements, we excluded PI values obtained during these

Table 1 Definitions of the variables

Variables	Definitions
PI-O	PI in the upper extremity of the operating side
PI-CL	PI in the upper extremity contralateral to the operating side
PI-O/PI-CL	PI in the operating side compared to the contralateral (PI-O divided by PI-CL)
Relative PI-O/PI-CL	Relative PI-O/PI-CL value compared to the baseline
(Prefix) Baseline-	The initial 3 minutes after position change; the prefix indicates the mean value of each corresponding variable during that period
(Prefix) Intraoperative-	The period after the baseline (control group) or after the blockade (study groups); the prefix indicates the mean value of each corresponding variable during that period
Procedure time	Duration between the position change and the end of the procedure (block)
Onset time	From the start of the procedure (position change) to the onset of the sympathetic blockade (50% increase of PI-O/PI-CL from the baseline, i.e., 1.5 of relative PI-O/PI-CL)

PI, perfusion index.

time periods. Specifically, PI values collected during the 20 seconds before and after the blood pressure measurements were discarded.

Sample size

The sample size of the first pilot study was based on our previous study (19). We found that the intraoperative PI after general anesthesia in non-cardiothoracic surgery was 3.1 (mean) with a standard deviation (SD) of 1.6. Assuming that intraoperative PI in thoracic surgery would be similar, with a mean of 3.0 and a SD of 1.5, we calculated that 10 subjects would be required for the study group to detect a 50% of PI difference (i.e., 1.5) (20) between two dependent means (before and after the blockade) with 80% power, two-sided significance level 5%. We planned to recruit the same number of participants for the control group. In light of the possibility of data loss, we decided to increase the sample size by adding two extra subjects per group, resulting in a total of 24 participants.

In the second pilot study, a sample size of 12 was needed to detect 50% increase in PI with 95% power and two-sided significance level 5%, based on the data of the first pilot study which showed baseline PI of 5.5±2.3. To account for possibility of data loss, sample size was increased to 14.

Statistical analysis

Statistical analyses were conducted on a per-protocol basis using R software version 4.0.3 (R Project for Statistical Computing, Vienna, Austria). Continuous variables were reported as mean ± SD or median (1Q, 3Q) based on the results of Shapiro-Wilk tests for assessing normality, and the data were analyzed using one-way analysis of variance (ANOVA) or the Kruskal-Wallis test as appropriate. *Post-hoc* pairwise comparisons of outcome were conducted using Dunn's test with P value adjusted using the Bonferroni method. A two-tailed P value <0.05 was considered statistically significant.

Results

A total of 48 subjects were assessed for eligibility, 32 in the first study and 16 in the second. Eight subjects were excluded in the first study based on the exclusion criteria (n=2), lack of informed consent (n=2), and due to an unexpected error in the recording system detected prior to surgery (n=4). Two subjects were excluded in the second study based on the exclusion criteria. Five subjects were withdrawn from the analysis due to data loss. Additionally, two subjects in the ITPB group were withdrawn, one due to unexpected change in the operating schedule (which was incompatible with the research schedule), and the other due to the inability to perform the planned blockade because of poor visualization during ultrasound scanning. Ultimately, 31 subjects (10, 11, and 10 for the control, PVB, and ITPB group, respectively) were included in the final analysis (*Figure 1*). Clinical characteristics of the included patients are summarized in *Table 2*.

PI changes in representative cases in each group are
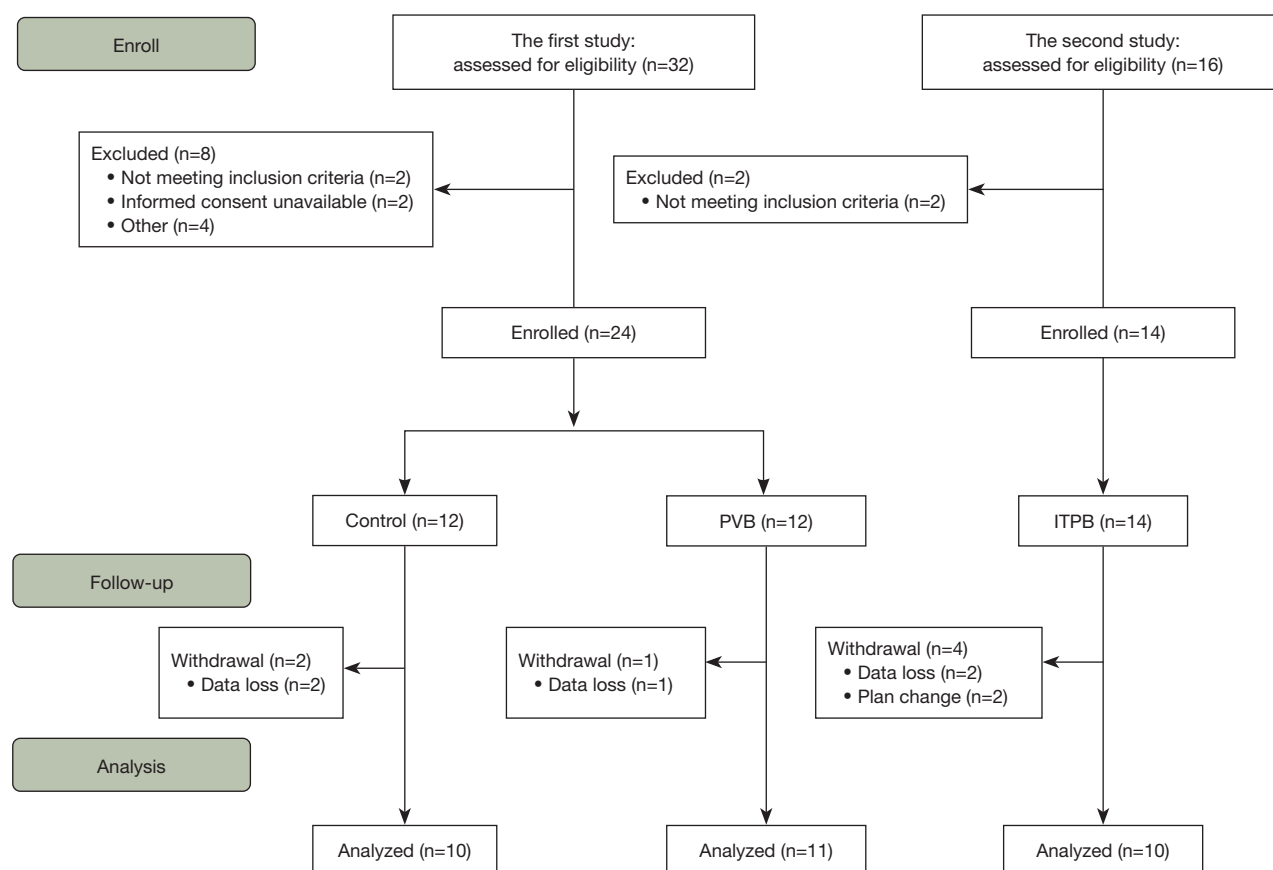
Figure 1 Patient flow diagram. PVB, paravertebral block; ITPB, intertransverse process block.

shown in *Figure 2* and every individual cases are shown in supplementary material (Appendix 1). The average procedure times were 10.1±3.8 and 7.6±0.9 minutes in PVB and ITPB groups, respectively. PI values of the entire subjects stratified by the group and monitoring side are shown in *Figure 3*. Noticeable increases of PI-O were observed from the initiation of the procedure, reaching its peak approximately 10–15 minutes later. While the relative PI-O/PI-CL value in the control group generally remained around 1—indicating a consistent ratio of PI between both sides of the upper extremity—occasional fluctuations exceeding 1.5 were observed. Consequently, we considered only the periods from the procedure's commencement to 5 minutes after the end of blockade (during surgical draping) as valid for assessing PI changes resulting from the blockade. Significant alterations following the blockades were evident in all cases within the PVB and ITPB groups, with onset times recorded at 7.7±3.8 and 6.9±2.8 minutes, respectively.

A concise summary of the measured variables is presented in *Table 3*. The intraoperative relative PI-O/PI-CL was 0.9 (0.8, 1.4), 2.1 (1.4, 2.5), and 1.4 (0.9, 1.9) in the control, PVB, and ITPB group, respectively (P=0.01). Pairwise comparison revealed a significant difference only between the control and PVB groups (adjusted P=0.01).

Discussion

This study demonstrated increases in PI in the ipsilateral upper extremity following PVB and ITPB. The increase in PI was assessed relative to the contralateral side and baseline (relative PI-O/PI-CL). Dramatic increases in ipsilateral PI were observed in the majority of PVB cases, indicative of unilateral sympathetic blockade. On the contrary, ITPB cases exhibited less pronounced increases in PI, with some cases not showing notable changes, although all cases met the criteria for a significant increase, at least briefly. To our knowledge, this is the first study to illustrate intraoperative

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Table 2 Clinical characteristics

Characteristics	Control (n=10)	PVB (n=11)	ITPB (n=10)	P
Sex (F)	2 (20.0)	2 (18.2)	6 (60.0)	0.07
Age (years)	67.5 (57.0, 76.0)	62.0 (56.5, 65.0)	63.5 (61.0, 69.0)	0.44
Height (cm)	166.1±7.2	168.6±7.0	159.0±6.2	0.01
Weight (kg)	66.9±11.4	64.8±6.7	59.4±8.4	0.17
BMI (kg/m^2)	24.3±4.7	22.8±1.8	23.5±3.1	0.57
Comorbidities				
HTN	7 (70.0)	3 (27.3)	4 (40.0)	0.13
DM	5 (50.0)	1 (9.1)	4 (40.0)	0.11
CAD	0	0	1 (10.0)	0.33
CVD	1 (10.0)	1 (9.1)	1 (10.0)	0.99
Anesthesia duration (min)	138.0 (120.0, 184.0)	124.0 (109.0, 152.0)	112.5 (99.0, 145.0)	0.31
Fluid intake (mL/h)	308.4±143.2	354.7±144.5	267.0±85.5	0.30
Remifentanil (μg/kg/min)	0.093±0.025	0.069±0.013	0.080±0.019	0.03

Data are reported as number (%), median (1Q, 3Q), or mean ± SD. PVB, paravertebral block; ITPB, intertransverse process block; F, female; BMI, body mass index; HTN, hypertension; DM, diabetes mellitus; CAD, coronary artery disease; CVD, cerebrovascular disease; SD, standard deviation.
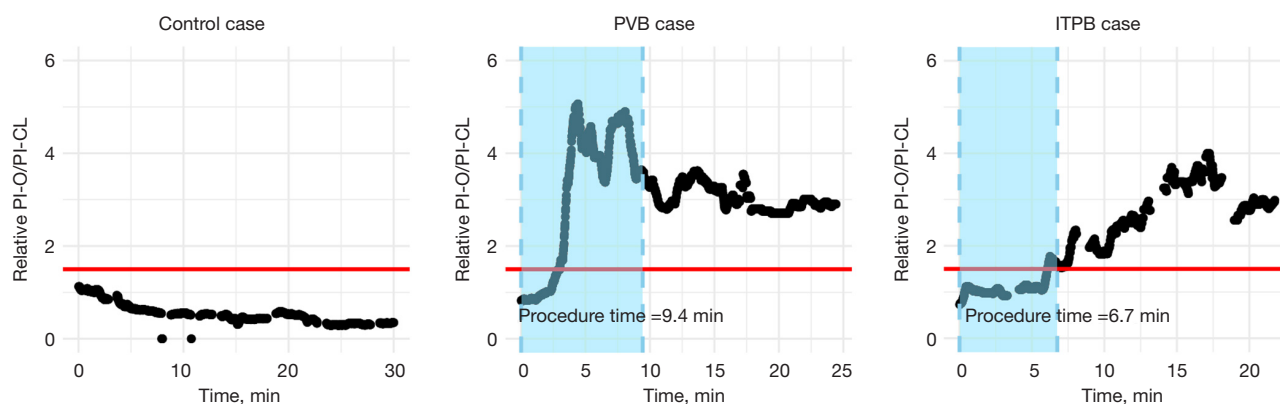

Figure 2 PI values of sample cases in each group. PI-O were adjusted after the PI-CL and baseline (yielding relative PI-O/PI-CL). The baseline was defined as the mean of the initial 3 minutes after position change (therefore, initial relative PI-O/PI-CL =1). The starting point (time 0) of the figure indicates position change and the sky-blue shaded area indicates procedure time (from position change to block end). Red horizontal solid line indicates a factor of 1.5 times baseline PI-O/PI-CL, which is considered a meaningful change. PI-O, PI values of the operating side; PI-CL, PI values of the contralateral side; PI, perfusion index; PVB, paravertebral block; ITPB, intertransverse process block.

changes in PI after these blockades. The study also revealed that these increases in PI were not consistently sustained throughout the surgery and could occur even without any blockade. This implies that changes in PI-O/PI-CL may not always correlate exclusively with the success of the blockade but are also influenced by other factors.

To account for systemic factors prone to fluctuations induced by general anesthesia and surgical stimuli, such as sympathetic tone, hemodynamics, and temperature—factors that, in turn, affect the PI (19,21)—we implemented bilateral monitoring of PI. By observing changes in the adjusted value, PI-O/PI-CL, we could discern whether
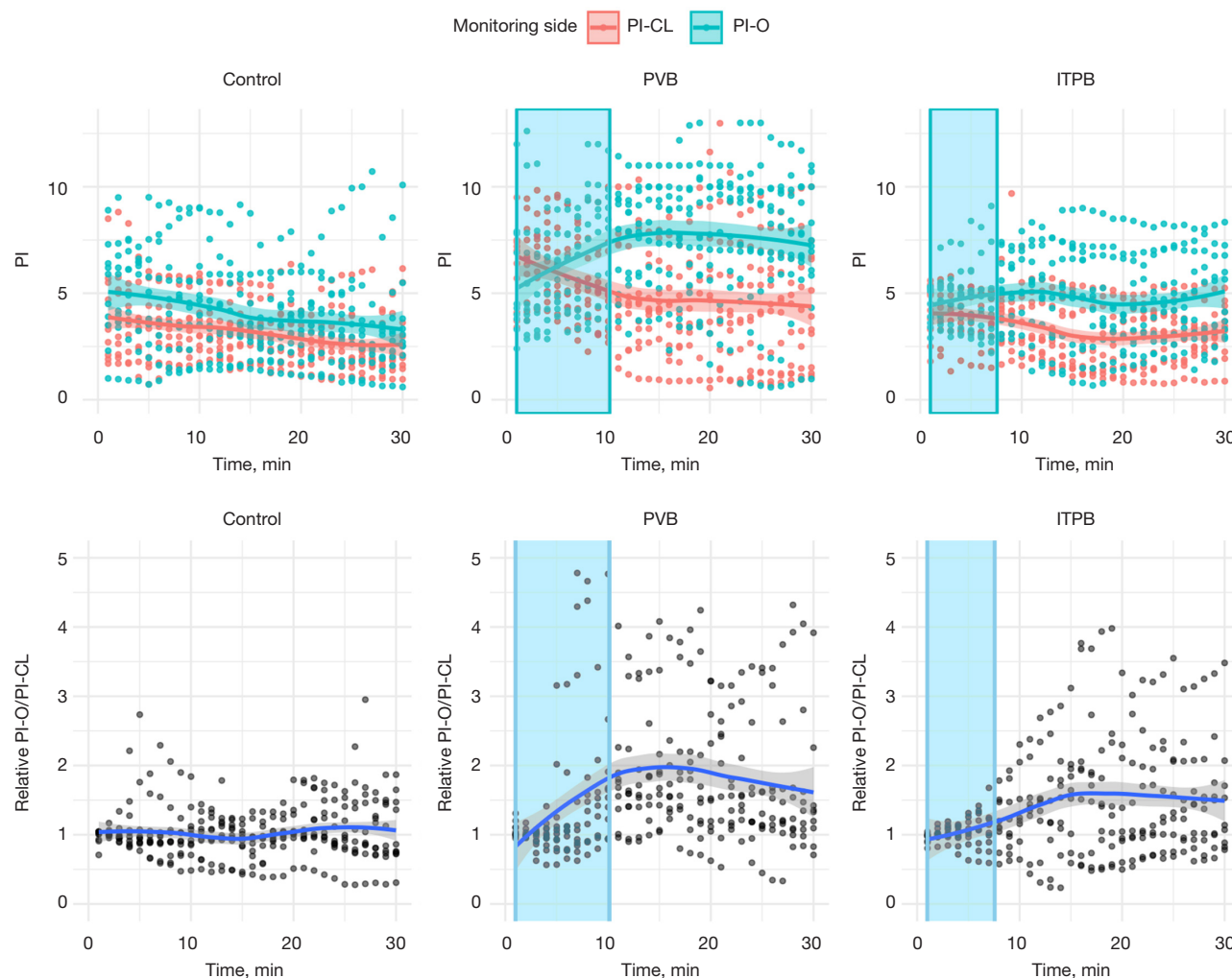
Figure 3 Group-wise stratification of PI changes in entire subjects. The starting point (time 0) of the figure indicates position change and the sky-blue shaded areas indicate mean procedure time (block). PI values depicted in the figure are 1-minute averaged values. Only the initial 30 minutes are shown to better depict the initial changes of PI values. Points in the upper panel is raw PI values (PI-O, PI-CL), and the lower panel is adjusted values (relative PI-O/PI-CL, relative to the contralateral side and baseline). The baseline in the lower panel is defined as the mean of the initial 3 minutes after position change. Therefore, the adjusted value in the lower panel starts from 1 (baseline). Smoothed solid lines indicate regression line of each side of PI values using loess function (locally estimated scatterplot smoothing). Shaded are of each line indicate 95% confidence interval. PI-CL, PI values of the contralateral side; PI-O, PI values of the operating side; PI, perfusion index; PVB, paravertebral block; ITPB, intertransverse process block.

the increase in PI values was induced systematically or regionally (i.e., by the blockade). Unfortunately, however, hidden confounders seem to remain, leading to fluctuations in PI-O/PI-CL even in the absence of a blockade, as observed in the control group. Potential confounding factors may include imbalanced changes in perfusion or temperature of an extremity. This issue should be addressed in future studies with more meticulous PI monitoring and

carful patient positioning. Additionally, it is advisable to carefully control for hemodynamics and surgical stimuli to accurately determine changes in PI values before and after regional blockade or surgical sympathectomy.

It is important to note that the current study was a combined study of two pilot studies aimed at observing intraoperative changes in PI with (PVB or ITPB) or without (control) regional blockades within each group.

Table 3 Summary of the measurements stratified by group

Variables	Control (n=10)	PVB (n=11)	ITPB (n=10)	P
Procedure time (min)	NA	10.1±3.8	7.6±0.9	0.04
Onset time (min)	NA	7.7±3.8	6.9±2.8	0.61
Baseline PI-O	5.1±2.2	5.5±2.3	4.7±1.1	0.65
Intraoperative PI-O	3.5±1.5	6.7±2.7	4.5±1.7	0.004
Baseline PI-CL	3.8±2.0	6.6±1.8	4.1±1.2	0.001
Intraoperative PI-CL	2.8±1.1	4.5±2.7	3.0±1.1	0.09
Baseline PI-O/PI-CL	1.5±0.8	0.8±0.3	1.3±0.5	0.03
Intraoperative PI-O/PI-CL	1.4 (0.7, 2.0)	1.5 (1.3, 2.4)	1.7 (1.1, 2.4)	0.52
Intraoperative relative PI-O/PI-CL	0.9 (0.8, 1.4)	2.1 (1.4, 2.5)	1.4 (0.9, 1.9)	0.01

Data are reported as mean ± SD or median (1Q, 3Q). PVB, paravertebral block; ITPB, intertransverse process block; NA, not available; PI, perfusion index; PI-O, PI values of the operating side; PI-CL, PI values of the contralateral side; SD, standard deviation.

The study was conducted in a non-randomized fashion sequentially, with the first pilot study for PVB and control, followed by the second pilot study for ITPB. As these studies were not designed with a prior hypothesis specific to group comparison and power calculation, the result should be conceived as a hypothesis and framework generating measure rather than a confirmatory result. Future studies with proper sample size and randomization are needed to validate the results of the current study.

There has been a growing interest in paravertebral proxies and their underlying mechanisms that convey analgesic effects on the chest wall (1-9). Theoretically, the anterior spread of local anesthetic should occur through channels such as the costotransverse foramen to provide this analgesic effect, as supported by various cadaveric and anatomical studies (7-9). However, there is still limited evidence available from real clinical contexts. Therefore, the present study aimed to develop a clinically useful tool for the noninvasive detection of sympathetic blocks in an operating environment. This tool not only offers a way to better understand newly developed regional techniques but also addresses the scarcity of evidence in clinical settings. Furthermore, it may provide real-time intraoperative feedback for a successful surgical sympathectomy (22). Additional measures can be considered before emergence from anesthesia if expected changes are not observed after surgical sympathectomy or regional blockade.

In a previous study that reported an increase in upper extremity PI after PVB, an additional experimental setting was necessary (20). In that study, the blockade was administered before anesthesia and the surgical stimulus, with a distinct observation period of 30 minutes. Although this setup could offer more controlled data, it deviates from everyday clinical practice. In the current study, our aim was to establish a more practical approach for evaluating sympathetic blockade after paravertebral or its proxies, one that can be readily applied in clinical settings.

The majority of preganglionic fibers to the upper extremity originate from spinal segments T3 to T6, whereas postganglionic fibers to the arm stem from T2, with a lesser contribution from T3 ganglia (23). Consequently, the upper thoracic region holds significant importance in sympathetic blockade for the upper extremity (22,24). In a prior cadaveric study, PVB exhibited a more vertically extensive spread within the paravertebral space (approximately 2–4 vertebral levels), contrasting with ITPB, which displayed a more limited extent (about 1–2 vertebral levels) (25). Consequently, ITPB increases the likelihood of sparing T2 ganglia, potentially leading to an inconsistent elevation of PI in this study. Moreover, while not conclusively established, it is intuitively apparent that as an indirect injection technique (i.e., ITPB), it tends to induce a lesser degree of sympathetic block compared to a direct injection (i.e., PVB).

The rationale for employing the multiple injection technique in this study was drawn from existing literature on PVB, which indicated a variable and unpredictable distribution following a single injection (26,27). Despite some evidence supporting the efficacy of the single injection technique (28,29), we opted for multiple injections due to the current lack of reliability in single injection methods for ITPB in thoracic surgery. By standardizing block levels

in both PVB and ITPB, our emphasis was on the ventral spread of local anesthetic rather than its vertical distribution across multiple dermatomal levels. Notably, we set the uppermost target at T3, as areas beyond this level are considered less relevant for achieving analgesia in thoracic surgery.

This study presents several limitations. Firstly, the success of blockade was solely determined based on sonographic endpoints, such as the downward movement of the pleura or bulging of the intertransverse tissue complex during injection. Future studies would benefit from a more comprehensive evaluation, including detailed assessments of dermatomal coverage and postoperative pain scores. Secondly, despite adjustments for the contralateral side and baseline, the newly derived tool (i.e., relative PI-O/PI-CL) may not exclusively reflect the success of the blockade. A more stable and controlled environment, especially in the immediate pre- and post-blockade phases, would yield more reliable results. Thirdly, since three levels of blockades were conducted in this study, the distinct contribution of each level to changes in PI cannot be analyzed. Determining the success of sympathetic blockade for lower thoracic levels based on upper extremity PI may be misleading. Fourthly, we were unable to include a true control group in thoracic procedures. Since incorporating a regional blockade as part of multimodal analgesia is a widely accepted standard, omitting a blockade for a research purpose was clinically unfeasible. Instead, we included a urologic procedure group as a control group, which currently lacks routine regional blockade for analgesia.

Conclusions

In conclusion, the study suggests that PVB results in a noticeable unilateral increase in upper extremity PI, whereas ITPB tends to induce a more inconsistent and lesser degree of increase. While monitoring PI values can serve as an indicator of upper extremity sympathetic blockade, it is essential to acknowledge potential confounders during surgery that may impact these observations. It is important to emphasize that the present study serves as a preliminary exploration, and further research, particularly through randomized trials, is needed to validate these findings conclusively.

Acknowledgments

Footnote

Reporting Checklist: The authors have completed the TREND reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-69/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-69/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-69/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study followed the Good Clinical Practice guidelines and the principles of the Declaration of Helsinki (as revised in 2013). The protocol was approved by the Institutional Review Board of Chungnam National University Hospital (1, CNUH 2022-07-078; 2, CNUH 2023-04-042) and was registered prior to patient enrollment at cris.nih.go.kr (1, KCT0007668; 2, KCT0008508). Written informed consent was obtained from all enrolled participants before surgery.

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