Prospective Study

Sympatholytic Effect of the High Thoracic Erector Spinae Plane Block

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Background: The erector spinae plane block (ESPB), which was introduced for the management of thoracic pain, is a technically easy and relatively noninvasive ultrasound (ULSD)-guided technique. Although the ESPB is used widely in variable clinical situations, its sympatholytic effect has never been studied.

Objectives: The purpose of this study is to demonstrate the sympatholytic effect of the high thoracic ESPB by comparing the blocked and unblocked sides of patients' upper extremities, using the changes in the perfusion index (PI).

Study design: Prospective, single-group, and open-label study.

Setting: The study was carried out in the pain clinic of a tertiary university hospital.

Methods: This study included 47 patients with upper extremity pain and various diseases who received T2 or T3 ESPBs using 20 mL of 0.2% ropivacaine. For the evaluation of the sympatholytic effect, measurements were taken on the numeric rating scale (NRS), the neck disability index (NDI), and the PI.

Results: The PIs of the blocked sides demonstrated significant increases at 10, 20, and 30 minutes compared to the PIs of the baseline and unblocked sides ($P < 0.001$). The PI ratio at 10 minutes was 2.74 ± 1.65, which was the highest value during the measurement period. Until 30 minutes after the ESPB, the PI ratio was significantly higher in the blocked side than in the unblocked side. During the study period, significant reductions in NRS and NDI scores were found irrespective of disease entity.

Limitation: The period of PI measurement was only 30 minutes, so we could not determine the time point when the PI returned to the baseline value.

Conclusion: The high thoracic ESPB was effective in relieving upper extremity pain in diverse disease entities, and the PIs of patients' blocked sides demonstrated significant increases over the baseline value and contralateral unblocked sides.

Key words: Erector spinae plane block, perfusion index, numerical rating scale, upper extremity pain

Trial registry number: Clinical trial registry information service (NCT05723393).

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The erector spinae plane block (ESPB) is a relatively noninvasive, safer, and technically easy regional block that provides favorable analgesia to patients with acute and chronic neuropathic pain (1-5). Although the ESPB's first application was for the management of thoracic neuropathic pain (6), the technique is currently applied widely in variable clinical situations such as thoracotomy, laparoscopic cholecystectomy, gastrectomy, mastectomy, and spinal surgery (1-4).

The ESPB requires ultrasound (ULSD) guidance that enables the visualization of local anesthetic spread underneath the erector spinae (ES) muscles. The spinalis, longissimus thoracis, and iliocostalis muscles comprise the thoracic ES muscles, which run vertically along both sides of the vertebral column from the sacrum up to the skull base (7,8). The ESPB can be performed in the cervical, thoracic, and lumbar regions but has been used more widely in the upper or mid-thoracic areas than in the cervical or lumbar regions (7).

The ESPB performed at the T2 level of the cadaver demonstrated an injected dye distribution ranging from C4 to T10. Also, 36% of cadavers showed the spread of an injected dye to the ventral ramus, the dorsal ramus, the paravertebral space (PVS), and even the contralateral side (9). Although the ESPB's exact action mechanism is still unclear, the analgesic effect is thought to activate by blocking the ventral and dorsal rami of the spinal nerves and diffusion into paravertebral space (9-11). Unlike the lumbar region, the thoracic PVS is very close to the sympathetic ganglion (12). The thoracic PVS is a wedge-shaped potential space. The apex and base of the thoracic PVS face the intercostal space and the posterior lateral side of the vertebral body, respectively. The contents of the thoracic PVS include the branching spinal nerve, intercostal vessels embedded in adipose tissue, and sympathetic nerve fibers (13). If local anesthetics injected during the thoracic ESPB procedure are diffused into the paravertebral space, the probable result is a sympatholytic effect. Case reports describing the sympathetic block after the high thoracic ESPB in patients with upper extremity complex regional pain syndrome (CRPS) have been recorded (14). Reports on the high thoracic ESPB also describe subsequent relief for visceral pain (15,16).

The perfusion index (PI) can reflect the perfusion status of the monitoring site by using the calculated parameters obtained from the special pulse oximeter. The advantages of the PI measurement are its simplicity, noninvasiveness, and ability to provide more quantitative information about peripheral circulation. The value of PI ranges from 0.02–20% and is expressed as the ratio (%) of the amplitude of the nonpulsatile signal to the pulsatile signal. The PI was found to be a more sensitive indicator for evaluating the effects of various interventions than the temperature (17,18).

The primary endpoint of this study was to evaluate the sympatholytic effect of the high thoracic ESPB, using numerical PI values and changes in numeric rating scale (NRS) scores.

Methods

Patients

This prospective, single-group, and open-label study was approved by our institutional review board (2023-01-025-01). The potential benefits and risks of this study were explained fully before patient enrollment, and patients provided informed consent. This study was registered before patient inclusion at ClinicalTrials.gov (NCT05723393).

Fifty-five patients aged between 20 and 80 years old who received a ULSD-guided T2 or T3 ESPB at the pain clinic were included. The main locations of the pain the patients complained about were the neck, shoulder, and arm areas. Causes of neck, shoulder, and arm pain included foraminal stenosis, spondylotic myelopathy, herniated intervertebral discs, complex regional pain syndrome, adhesive capsulitis, and post-thoracotomy pain. Patients with a history of allergic reactions to local anesthetics, coagulopathy, previous spine surgery, or peripheral arterial disease were excluded.

T2 or T3 ESPB under ULSD Guidance

One physician who had more than 7 years of experience with ULSD-guided injections performed this procedure. The physician began with a right- or left-sided unilateral ESPB. The side depended on the location of the neck pain and radiating arm pain. A patient was laid in prone position for the performance of a T2 or T3 ESPB. Using a linear high-frequency probe (GE HealthCare, Logiq S8) in the longitudinal position enveloped in a sterile polyvinyl sheath containing an ULSD gel, the physician confirmed the spinous process, the lamina, and the T2 or T3 transverse process by moving a probe serially from the midline to the lateral side of an upper thoracic spine. Once those areas were identified, a 100-mm, 23-gauge needle was inserted in-plane from the cephalad to caudad direction. The 20 mL of 0.2% ropivacaine was injected after the contact with the transverse process. Following this injection, the linear spread of local anesthetics beneath the ES muscle was confirmed. For the evaluation of pain reduction, the NRS score (0: no pain, 10: worst pain imaginable) was obtained before the ESPB and 30 minutes, 2 weeks, and 4 weeks after the ESPB. To confirm an improvement in functional disability, the neck disability index (NDI; 0–4: no disability; 5–14: mild disability; 15–24: moderate disability; 25–34: severe disability; > 35: complete disability) (19) was obtained in patients with cervical spine disease before the ESPB and 4 weeks after the ESPB.

Irrespective of pain relief, all patients received the

ESPB twice. The second ESPB was performed 2 weeks after the first injection. At 4 weeks, a patient's pain relief was observed without any ESPB. The NRS score was obtained by asking, "What was your average pain score over the past 24 hours?"

Measurement of PI

For the proper evaluation of the changes in PI values, the ambient temperature was set to 23–26°C. The ambient temperature was measured at a remote site from the heat-generating equipment. One hour before the measurement of the PI changes, all patients were educated to avoid smoking, alcohol intake, and severe exercise, all of which might affect peripheral circulation. All patients were laid in bed for 10 minutes under an ambient room temperature before the measurement of the baseline PI. The PI was measured using a Masimo pulse oximetry (Masimo Corp) sensor attached to the index finger. All PI values were measured at 2-minute intervals until 30 minutes after local anesthetic injection in both the blocked and the contralateral unblocked upper extremities using 2 independent Masimo pulse oximeter sensors. Since ESPB was performed twice in each patient, the PI was measured at each time of the ESPB procedure. The final value of ESPB in each patient was the mean value of the PI of 2 ESPBs. The PI values were recorded automatically by the Masimo instrument configuration tool (Masimo Corp) data extraction system. While the PI values were measured, patients were laid in bed in a supine position with unnecessary movement limited.

The PI ratio was calculated as the ratio between the PI at a specific time point after local anesthetic injection and the baseline PI. The specific time points when the PI ratios were obtained included 6, 10, 20, and 30 minutes after ESPB. All PI values and PI ratios obtained from the blocked sides were compared to those obtained from the unblocked sides.

Statistics

We assessed the sympatholytic effect of the T2 or T3 ESPB by the changes in the NRS, PI, and PI ratios. Since there were no studies that used PI values to show the sympatholytic effect of the high thoracic ESPB, we performed our preliminary study. Because we assumed the mean difference of the PI ratio between the blocked and unblocked sides was 0.9 ± 1.3, the α error level was 0.05, the β error level was 0.2, and the dropout rate was 15%, 41 patients were required.

To compare the changes in the PI and PI ratios at multiple time points between the blocked and the unblocked side, we employed the analysis of variance for repeated measures with post hoc pairwise comparisons, using the Bonferroni test in SPSS® software version 20 (IBM).

Results

Fifty-five patients were assessed for eligibility. Five patients refused to participate in this study. Fifty patients who received a ULSD-guided T2 or T3 ESPB enrolled in this study. Among them, 3 patients did not visit the pain clinic at the 4-week follow-up period. Overall, 47 patients completed this study (Fig. 1). Patient demographic and clinical data are presented in Table 1. The most commonly included patient diagnoses were cervical foraminal stenosis and herniated intervertebral discs (Table 1).

The baseline PI of the blocked side was comparable to that of the unblocked side. The PI of both sides was less than 3 (2.63 ± 1.86 vs. 2.37 ± 1.19). The PI of the blocked side demonstrated significant increases at 10, 20, and 30 minutes compared to the baseline PI ($P < 0.001$, Table 2). Also, the PI of the blocked side showed a significant increase compared to that of the contralateral unblocked side ($P < 0.001$, Table 2). The PI started to increase significantly at 4 minutes after the ESPB, and the PI at this time point was nearly double the baseline value. The peak increase in PI was observed at 10 minutes after the ESPB (Fig. 2). The PI value at 10 minutes was nearly triple the baseline PI value (Table 2, Fig. 1). At the 30-minute PI measurement mark, the increase in the PI was maintained until 30 minutes after

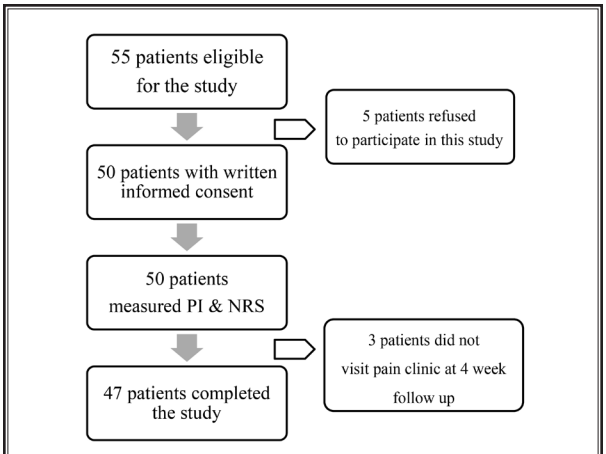

Fig. 1. *Flow chart of the study.*
PI: perfusion index; NRS: numerical rating scale.

Table 1. *Patient demographic and clinical data.*

	Value
Age (years)	58.7 ± 11.4
Gender (M/F)	30 (62.5) / 18 (37.5)
Body mass index (kg/m^2)	23.5 ± 3.9
Diagnosis	
Foraminal stenosis	23 (47.9)
Spondylotic myelopathy	2 (4.2)
Herniated intervertebral disc disease	16 (33.3)
Complex regional pain syndrome	3 (6.3)
Adhesive capsulitis	1 (2.1)
Post-thoracotomy pain	2 (4.2)
Herpes zoster	1 (2.1)
Duration of pain	
< One month	5 (10.4)
One-3 months	24 (50.0)
> 3 months	19 (39.6)
Injection side	
Left / Right	27 (56.3) / 21 (43.8)

Table 2. *Changes in PI over time.*

Perfusion index	Blocked side (n = 47)	Unblocked side (n = 47)	*P* value
Baseline	2.63 ± 1.86	2.37 ± 1.19	0.386
10 min	5.42 ± 2.34*	2.72 ± 1.19	< 0.001
20 min	4.52 ± 2.02*	2.78 ± 1.19	< 0.001
30 min	3.98 ± 1.84*	2.43 ± 0.96	< 0.001

Values are mean (SD). *P < 0.001 vs baseline.

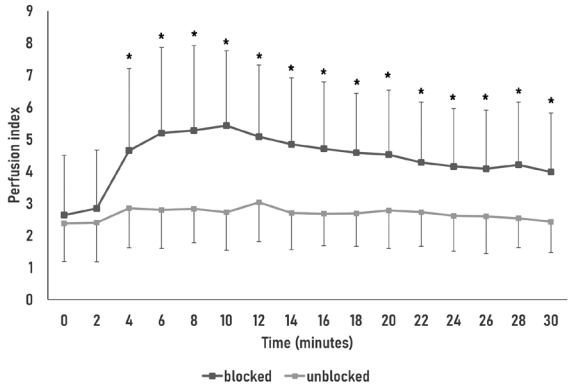

Fig. 2. *PI values at 2-min interval in the blocked and the unblocked side.*
*P < 0.05 (blocked vs. unblocked side).

the ESPB, and this increase was significant compared to the unblocked side (P < 0.05, Fig. 2).

The PI ratio was highest at 10 minutes after the ESPB. During the whole PI measurement period, the PI ratio was significantly higher in the blocked side than in the unblocked side (Table 3). During the study period, significant reductions in NRS and NDI scores were found irrespective of disease entity (Figs. 3, 4).

No major side effect was observed after an ESPB at the T2 or T3 level.

Table 3. *Changes in PI ratio over time.*

PI ratio	Blocked side (n = 47)	Unblocked side (n = 47)	*P* value
6 min	2.42 ± 1.40	1.43 ± 0.92	< 0.001
10 min	2.74 ± 1.65	1.56 ± 1.80	0.001
20 min	2.32 ± 1.56	1.57 ± 1.73	0.021
30 min	2.00 ± 1.38	1.30 ± 0.95	0.005

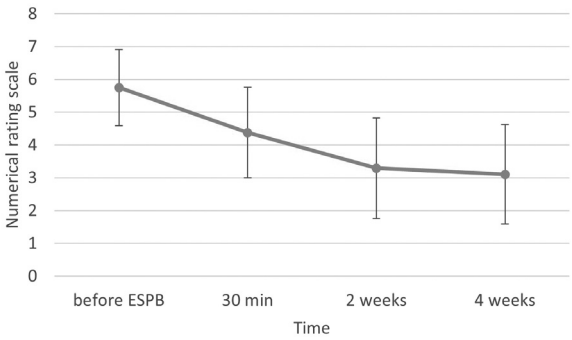

Fig. 3. *Changes in NRS score before and 30 min, 2 weeks, and 4 weeks after ESPB.*

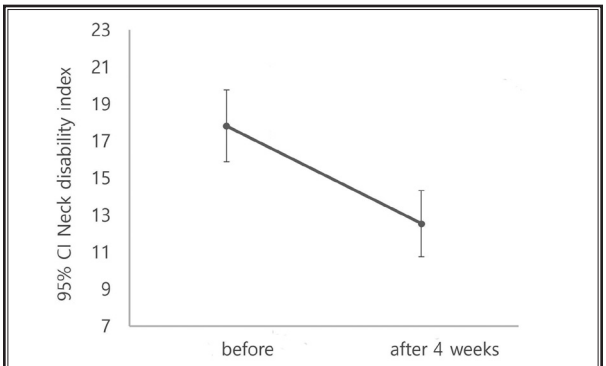

Fig. 4. *Changes in NDI scores before and 4 weeks after ESPB.*

Discussion

In this study, we demonstrated the sympatholytic effect of the high thoracic ESPB, using the changes in PI values and NRS scores. The PI ratio demonstrated a significant increase from the contralateral unblocked side, and the highest increase in PI ratio was observed at 10 minutes after ESPB. The NRS score also showed a significant decrease from the baseline value.

The PI analyzes the peripheral blood circulation, using the wave form obtained from the photoplethysmography. Pulsatile and nonpulsatile signals, which comprise the PI, are numerical values for the ratio between the pulsatile and nonpulsatile blood flow. Pulsatile flow is regulated by vessel tension, preload, and vasoactive drugs, whereas nonpulsatile flow is affected by venous tension and body fluid volume (17,18,20,21). If a peripheral nerve block or neuraxial block is performed successfully, the procedure can affect sympathetic nerve activity, which results in increased peripheral blood flow with a high proportion of the pulsatile signal. This high proportion results in increased PI, which provides an objective method for predicting the success of a peripheral nerve block (20,22). The ESPB is a fascial plane injection that has different characteristics from a peripheral nerve block or a neuraxial block. The sympatholytic effect of the ESPB has never been suggested by previous studies.

The PVS is a potential space where the local anesthetics used during ESPB can enter through the costotransverse foramen and the intertransverse connective tissue complex (1,14). This potential space has no defined cranial border, whereas its caudal end is considered to be L1. The PVS is continuous, communicates superiorly and inferiorly over the rib head, and can be compartmentalized into anterior and posterior sections by the endothoracic fascia (13). The therapeutic effect of the ESPB comes from the craniocaudal spread of local anesthetics over multiple vertebral levels in the fascial plane deep in the ES muscle, accompanied by the anterior diffusion into the nearby intercostal space and PVS (7,11). If the local anesthetics are injected in the vicinity of the PVS, a sympatholytic effect may occur, since the PVS contains the sympathetic nerve. The appearance of Horner's sign after a high thoracic paravertebral block would be evidence of such an effect (23).

Local vasodilatation, increased blood flow, and increased skin temperature were the physiologic findings when a successful sympathetic nerve block was achieved (18,24,25). When we determine the sympatholytic effect, subjective and objective methods should be used to decide the degree of the sympathetic block. The pain relief, warm sensation, changes in skin color, and anhidrosis correspond to the subjective assessment. Skin temperature measurements, provocation sweat tests, sympathetic skin tests, laser Doppler imaging, and the PI may represent objective assessment tools (18,22,25,26).

In clinical practice, observing an increase in the treated sides' skin temperature was the easy and widely accepted method for assessing the sympatholytic effect objectively. However, recent clinical studies have suggested that measuring the PI may be a superior substitute for skin temperature monitoring. According to previous studies, the PI was an earlier, clearer, and more sensitive measurement tool than the skin temperature monitoring increase and demonstrated a quicker response after various interventions (17,18). In patients with chronic CRPS, a disease with an altered peripheral circulatory environment, the use of PI demonstrated a more recognizable rapid response than did the observation of the temperature increase (18). According to this study, as early as 4 minutes after the ESPB, the PI started to increase significantly compared to the baseline value and that of the unblocked side. In contrast, the skin temperature did not start to increase significantly until at least 10 minutes after an epidural block or a lumbar sympathetic ganglion block (25).

A few studies have used changes in PI to demonstrate the success of peripheral nerve blocks (20,22). According to those studies, the PI was a useful assessment tool for the prediction of successful nerve blocks. Moreover, the PI and PI ratio at 10 minutes after a nerve block showed a sensitivity and specificity of 100% for the block's success (20).

A high thoracic ESPB in patients with upper extremity CRPS demonstrated significant decreases in NRS scores and in cold sensations in the affected upper extremities. Also, the incidences of breakthrough pain and the consumption of tramadol and fast-action oxycodone were reduced by nearly half (14). This study included 3 CRPS patients, who also demonstrated significant decreases in NRS scores and improvements to cold sensations.

CRPS is a chronic neuropathic pain condition that requires the sympathetic block for attenuating the disease progression and improving symptoms (27). The preferred locations of sympathetic blocks in the upper extremities have been the stellate ganglion and thoracic sympathetic ganglion at T2 or T3 (18,28). However, the thoracic sympathetic ganglion block is very invasive

and technically challenging, causing a risk of inadvertent intercostal or epidural spreading (29). Compared to the thoracic sympathetic ganglion block, the high thoracic ESPB is a technically easy and safe method. Even patients with altered hemostasis could be managed with ESPBs safely (7,30). In addition, this study's comparison of patients' blocked sides to the baseline value and contralateral sides may demonstrate the significant sympatholytic effect of the ESPB. Therefore, the high thoracic ESPB may be a good alternative for patients requiring sympatholytic effects.

This study includes several limitations. First, we evaluated the changes in NRS and NDI scores for the purpose of subjective measurement of sympatholytic effects. However, the included patients had diverse diseases, although all patients complained of upper extremity pain. If the patients involved had sympathetically mediated pain and identical disease entities, the ESPB's sympatholytic effect might have been demonstrated more effectively. In clinical situations, it is hard to find totally sympathetically mediated pain in the upper extremities. Even patients with CRPS present complex pathophysiology, including dysregulation of sympathetic activity, inflammation, and endothelial dysfunction (27,31-33). Second, the period of PI measurement was only 30 minutes. Therefore, we could not determine the time point when the PI returned to the baseline value. Third, we evaluated only the sympatholytic effect of the high thoracic ESPB specifically, not the success or failure of the ESPB generally. Further study evaluating the ESPB's success or failure is required.

Conclusion

In conclusion, the high thoracic ESPB was effective in relieving upper extremity pain in diverse disease entities, and the PI demonstrated a significant increase compared to the baseline value and contralateral unblocked side.

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