Prospective Study

Predictors of a Successful Outcome Following a Thoracic Erector Spinae Plane Block for Cervical Radiculopathy

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Background: The erector spinae plane block (ESPB) is an interfascial plane block for managing neuropathic thoracic pain. Although the ESPB is applied widely in various clinical situations, no studies have evaluated the association between the analgesic outcomes of the ESPB and the numerical changes in the perfusion index (PI) and PI ratio.

Objectives: The purpose of this study is to investigate the association between the clinical response following ESPB and other possible factors, including changes in the PI and PI ratio.

Study Design: A prospective, nonrandomized, and open-label study.

Setting: The pain clinic of a tertiary university hospital.

Methods: This study included 92 patients with neck or arm pain who received T2 ESPB using 20 mL of 0.2% ropivacaine. To aid in the prediction of clinical outcomes, the PI was measured at the blocked side for 30 minutes as soon as the ESPB was finished. Various demographic data were also analyzed to predict the clinical outcomes.

Results: Among 92 patients, 59 patients (64%) showed successful treatment outcomes (> 50% reduction in the numerical rating scale score or > 30% reduction in the neck disability index). The baseline PI of the responders was statistically higher than the nonresponders' ($P < 0.05$). Also, the responders' PI demonstrated statistically higher values than the nonresponders' at the time points of 4, 6, and 8 minutes after the ESPB. Multivariate logistic regression analysis revealed that a higher baseline PI (OR, 1.91; 95% CI, 1.27-2.86; $P = 0.002$) was an independent factor associated with a successful outcome.

Limitations: Only a small number of patients with nonspinal diseases were included, except for those who had cervical radiculopathy. Therefore, it is hard to conclude that thoracic ESPB has any therapeutic benefits to patients with nonspinal diseases such as complex regional pain syndrome, adhesive capsulitis, or post-thoracotomy pain syndrome.

Conclusion: A successful outcome at 4 weeks after T2 ESPB was achieved in 64% of patients with cervical radiculopathy. A higher baseline PI value was an independent factor associated with a successful response to T2 ESPB.

Key words: Erector spinae plane block, perfusion index, numerical rating scale, Neck Disability Index

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A degenerative process around the neural foramen or protruding material from the herniated disc can cause irritation and inflammation of the cervical nerve root, which leads to cervical radiculopathy (1,2). This affliction usually presents with radiating arm pain, sensory

deficits, numbness, tingling sensations, or even motor weakness in an upper extremity. Magnetic resonance imaging or computed tomography can confirm neurologic compression. Patients affected with cervical radiculopathy present favorable prognoses, and most patients improve spontaneously with only a focused, nonoperative treatment (1-3).

The erector spinae plane block (ESPB) is an interfascial plane block meant to manage neuropathic thoracic pain (4). Since the ESPB's introduction in 2016, many case reports and clinical researches have been published that report that the procedure exhibits good to excellent analgesic efficacy in various clinical situations (5-8). Other important benefits of the ESPB include its greater safety and technical ease than the neuraxial block. Even patients with altered hemostasis or activated partial thromboplastin time ratios or international normalized ratios exceeding 1.5 times the normal value could be managed with the ESPB safely (9).

Cervical epidural injection with or without steroids has been the widely accepted method of alleviating the symptoms of cervical radiculopathy (10). Recently, the high thoracic ESPB has been demonstrated to have equivocal treatment efficacy to cervical epidural injections (11). Considering the potentially catastrophic complications of these injections (12,13) (although such complications are not frequent) and the high thoracic ESPB's aforementioned equivocal treatment outcome (11), the high thoracic ESPB may be a good therapeutic alternative for treating cervical radiculopathy.

The perfusion index (PI) can reflect the perfusion status of the monitoring site, using the calculated parameters obtained from the special pulse oximeter. The advantages of PI measurement are the procedure's simplicity, noninvasiveness, and ability to provide more quantitative information about peripheral circulation (14). A previous study reported that the responder group (> 50% pain reduction) demonstrated a significantly higher PI ratio 5 minutes after the transforaminal epidural block (15). However, no studies have evaluated the association between the clinical outcomes of the ESPB and the numerical changes to the PI.

The primary goal of this study was to investigate the association between clinical outcomes following ESPBs in patients with cervical degenerative spinal disease and the numerical changes in the PI or PI ratio. Also, we aimed to identify other factors that could possibly predict a successful or poor response after the ESPB.

Methods

Patients

This prospective, single-group, and open-label study was approved by our institutional review board (2023-01-025-02). The potential benefits and risks of this study were explained fully before the patients enrolled, and they provided informed consent. This study was registered at ClinicalTrials.gov (NCT 05723380) before patient inclusion.

Ninety–two patients aged between 20 and 80 years who underwent ultrasound-guided T2 ESPB at the pain clinic were included. The inclusion criteria were as follows: (1) patients who had neck pain with or without arm pain due to foraminal stenosis, cervical spondylotic myelopathy, or herniated disc disease; (2) patients with anterior chest pain or shoulder pain due to herpes zoster, adhesive capsulitis, post-thoracotomy pain syndrome, or complex regional pain syndrome; (3) patients with an 11-point numeric rating scale (NRS) score (16) of > 4 within the previous week since the screening day; (4) patients with a Neck Disability Index (NDI) score > 15 (17).

The exclusion criteria were as follows: (1) patients with a history of allergic reactions to local anesthetics; (2) pregnant patients; (3) patients with spinal deformities; (4) patients with a history of cervical spine surgery; (5) patients experiencing coagulation abnormalities; (6) patients who had peripheral arterial disease or who were taking any medication that affected the peripheral circulation; and (7) patients who require bilateral ESPBs.

T2 ESPBs Under Ultrasound Guidance

One physician who had > 10 years of experience with ultrasound-guided injections performed this procedure. Right- or left-sided unilateral T2 ESPBs were performed. The patient was laid in a sitting or prone position for the performance of T2 ESPB. Using a linear high-frequency probe (Logiq™ S8, GE Healthcare) in the longitudinal position, enveloped in a sterile polyvinyl sheath containing an ultrasound gel, the spinous process, lamina, and T2 transverse process were confirmed by serially moving a probe from the midline to the lateral side of the thoracic spine. Once the physician identified the tip of the transverse process, a 100-mm, 22-gauge echogenic needle was inserted in the plane from the cephalad to the caudal direction. Twenty mL of 0.2% ropivacaine was injected after contact with the transverse process was established. Following this injection, the linear spread of local anesthetics beneath

the erector spinae (ES) muscles was confirmed. For the evaluation of pain improvement, the NRS score (0: no pain, 10: worst pain imaginable) was obtained before ESPB and at 30 minutes, 2 weeks, and 4 weeks after ESPB. The NRS score was obtained by asking, "What was your average pain score over the past 24 hours?"

The NDI (0–4: no disability; 5–14: mild disability; 15–24: moderate disability; 25–34: severe disability; >35: complete disability) (18) was evaluated before administering the ESPB and 4 weeks after the procedure. The NDI, which is a simple, short, and self-reported questionnaire consisting of 10 items that evaluate the patient's ability to perform physical activities, was first introduced in 1991 (17). The NDI was adapted cross-culturally for Korean patients and validated (18).

All patients included in the present study received an ESPB once or twice. Patients who showed near complete pain relief after the first ESPB did not receive any additional ESPBs. The second ESPB was performed 2 weeks after the first injection.

To identify factors that were possibly related to the clinical outcome, patients were divided into responders and nonresponders. Responders were patients who showed > 50% improvement to pain (> 50% reduction of NRS score) or improvement to disability (> 30% reduction of NDI score). Nonresponders were patients who showed < 50% improvement to pain (< 50% reduction of NRS score) or improvement to disability (< 30% reduction of NDI score).

All demographic data, including age, body mass index, diagnosis of spine, duration of pain, and injection side were obtained by reviewing the electronic medical records and were further analyzed to predict successful outcomes. Specifically, the pain location was subdivided into neck pain only, arm pain only, and neck pain with arm pain.

Measurement of PI

The ambient temperature of the pain clinic was set to 23–26°C for the proper evaluation of the changes in PI values. 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 instructed to avoid smoking, alcohol intake, and severe exercise, which might have affected peripheral circulation. All patients were laid in bed for 10 minutes under an ambient room temperature before the measurement of the baseline PI. The measurement used a Masimo® pulse oximetry (Masimo® Corp) sensor attached to the index finger. All PI values were measured at 2-minute intervals, using Masimo® pulse oximeter sensors, until 30 minutes after the injection of local anesthetics in the blocked upper extremity. The PI values were recorded automatically by the Masimo® instrument configuration tool's (Masimo® Corp) data extraction system.

The PI was measured each time the ESPB was performed, which was either once or twice. Therefore, the mean value of the PI measured during 2 ESPBs was used for the final analysis. While the PI values were being measured, patients were laid in bed in a supine position, with unnecessary movement restricted.

The PI ratio was calculated as the ratio between the PI at a specific time point after a local anesthetic injection and the baseline PI. The PI ratios were obtained at the time points of 4, 10, 20, and 30 minutes after the ESPB.

Statistics

The Kolmogorov-Smirnov test was used to examine normal distribution. If the test showed normal distribution, an independent Student's t-test was used to compare the continuous variables between the responder and nonresponder groups. Categorical variables were reported as the number of patients (%) and compared using Pearson's chi-squared test or Fisher's exact test. A repeated measures ANOVA with post hoc pairwise comparisons using the Bonforroni test was employed to compare the changes in PI ratios and NRS scores at multiple time points between the responder and nonresponder groups. Univariate and multivariate analyses were performed to identify the possible outcomes of predictive factors associated with a successful response. Variables with *P*-values of < 0.1 on a univariate logistic regression analysis were included in multivariate logistic regression analyses (SPSS Statistics Version 20, IBM). A *P* value of < 0.05 was considered statistically significant. The odds ratio (OR) and 95% confidence interval (CI) for successful outcomes of thoracic ESPB were calculated by logistic regression analyses.

Results

A total of 103 patients were evaluated for eligibility in this study; however, 8 patients were excluded, since they met the exclusion criteria. Three patients did not visit the pain clinic at the 4-week follow-up. The remaining 92 patients were allocated into the responder or nonresponder group based on the results of the NRS or NDI reduction. Among 92 patients, 59 patients (64%) showed successful treatment outcomes (> 50% reduc-

tion of NRS score or > 30% reduction of NDI score) and they were allocated into the responder group (Fig. 1).

The patient demographic data were similar between the responder and nonresponder groups. The most common cervical spine disease was foraminal stenosis, followed by herniated disc disease (Table 1). Included nonspinal diseases were herpes zoster, adhesive capsulitis, complex regional pain syndrome, and post-thoracotomy pain syndrome.

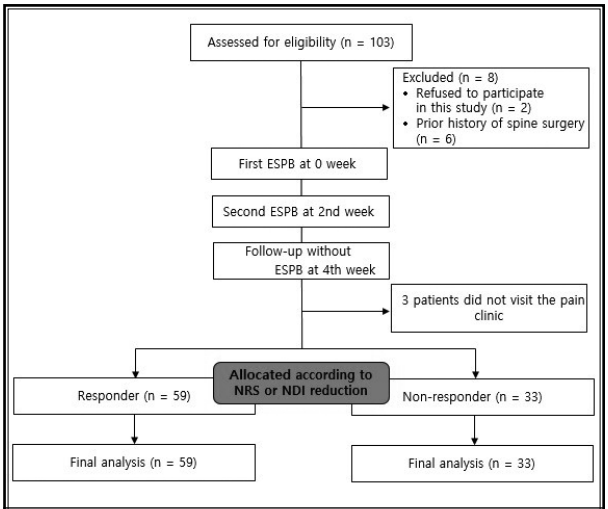

Fig. 1. *Flow chart of the study.*
NRS: numeric rating scale.

The baseline PI of the responder group was statistically higher than that of the nonresponder group (*P < 0.05, Fig. 2). During the 30-minute period of PI measurement, the responder group maintained a higher PI than did the nonresponder group. In particular, the responder group's PI demonstrated statistically higher values than the nonresponder group did at the time points of 4, 6, and 8 minutes (*P < 0.05; **P < 0.005, Fig. 2). The PI ratio of the responder group was higher than that of the nonresponder group at 4, 10, 16, and 30 minutes after ESPB but did not show any statistically significant differences (Table 2). The responder group's NRS and NDI scores demonstrated significant reduction at 4 weeks after the ESPB (P < 0.001, Table 3,4).

Univariate and multivariate logistic regression analysis revealed that a higher baseline PI (OR, 1.91; 95% CI, 1.27-2.86; P = 0.002) was an independent factor associated with successful outcomes (Table 5). Demographic data, pre-injection symptoms, and disease type were not associated with successful outcomes.

Discussion

In this study, a successful outcome at 4 weeks after a T2 ESPB was achieved in 64% of patients with cervical radiculopathy. The higher baseline PI value was an independent factor associated with a successful response to a T2 ESPB.

Epidural injections with or without steroids have

Table 1. *Patient demographic and clinical data.*

	Responders (n = 59)	Nonresponders (n = 33)	Total (n = 92)	*P*-value
Age (years)	61.7 ± 11.4	57.0 ± 10.7	60.0 ± 11.3	0.054
Gender (male)	33 (55.9)	22 (66.7)	55 (59.8)	0.378
Body Mass Index (kg/m^2)	23.71 ± 2.65	22.81 ± 2.98	23.39 ± 2.79	0.140
Diagnosis				0.060
Foraminal stenosis	43 (72.9)	19 (57.6)	62 (67.4)	
Cervical spondylotic myelopathy	2 (3.4)	0 (0.0)	2 (2.2)	
Herniated disc disease	11 (18.6)	9 (27.3)	20 (21.7)	
Herpes zoster	2 (3.4)	0 (0.0)	2 (2.2)	
Complex regional pain syndrome	0 (0.0)	3 (9.1)	3 (3.3)	
Post-thoracotomy pain syndrome	1 (1.7)	1 (3.0)	2 (2.2)	
Adhesive capsulitis	0 (0.0)	1 (3.0)	1 (1.1)	
Duration of Pain				0.064
< 3 months	33 (55.9)	15 (45.5)	48 (52.2)	
3 – 12 months	26 (44.1)	15 (45.5)	41 (44.6)	
> 12 months	0 (0.0)	3 (9.1)	3 (3.3)	
Injection side (left)	30 (50.8)	16 (48.5)	46 (50.0)	0.828

Values are mean ± SD or number of patients (%).

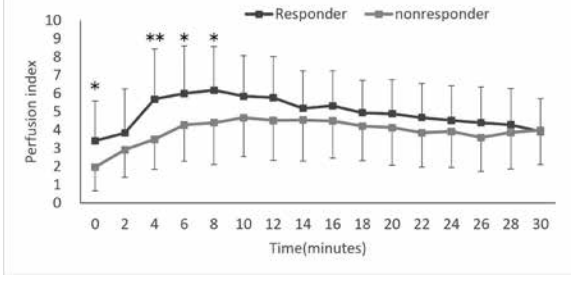

Fig. 2. *Changes to the perfusion index values at different time points in the responder and non-responder groups.*
* $P < 0.05$; ** $P < 0.005$

been the widely accepted treatment modality for treating cervical radiculopathy (10). For successful cervical epidural injections, fluoroscopy or computed tomography guidance is always required, which leads to radiation exposure for both physicians and patients. Moreover, life-threatening complications after cervical transforaminal epidural injections have been reported, including brain and spinal cord infarctions, quadriplegia, paraplegia, and pneumocephalus (12,13). When a thoracic ESPB at the T2 level was performed using a high volume of local anesthetics, it could result in an analgesic effect similar to that associated with cervical epidural injections (11). Accordingly, a successful outcome was achieved in 68.5% of patients who received cervical interlaminar epidural injections and in 49.1% of patients who received cervical transforaminal injections (19). A recent study showed that when patients with cervical radiculopathy were treated with cervical interlaminar epidural injections, 58.9% of the patients could be sorted into a responder group (10). In the present study, the proportion of successful outcomes of ESPBs was similar to those seen in previous studies of cervical epidural injections (10,19,20). Further study is required to determine if thoracic ESPBs have therapeutic effects that are similar to or better than those associated with other interventional pain procedures for cervical radiculopathy.

Originally, the thoracic ESPB was the widely accepted method for the management of intra- or postoperative pain, not for treating cervical radiculopathy (6,8,21-26). However, we assumed that cervical radiculopathy caused by degenerative cervical spine disease could be treated effectively by applying T2 ESPBs, since the local anesthetics injected during T2 ESPBs demonstrated anterior diffusion to the cervical neural foramen, ventral, and dorsal ramus (4,27,28).

The craniocaudal distribution of the local anesthetic in the fascial plane located deep to the ES muscles is thought to be an important factor in the ESPB's analgesic effect. A previous cadaver study demonstrated a wide and variable distribution of dye, ranging from C4 to T11 when a T2 ESPB was performed (28). The ultimate locations in which injected local anesthetics exert their effects are thought to be the cervical neural foramen and the ventral and dorsal rami. When local anesthetics reached the fascial plane deep to the ES muscles, they diffused in anterior, posterior, and lateral directions to reach the aforementioned location (29). Unlike the T2 ESPB, an ESPB at the cervical level might possibly deliver local anesthetics to the cervical neural foramen and ventral and dorsal rami. However, performing an ESPB at the cervical level is technically more difficult than at the thoracic level and poses a potential risk of phrenic nerve block (30).

Table 2. *Perfusion index (PI) ratio over time.*

PI ratio	Responders (n = 59)	Nonresponders (n = 33)	*P*-value
T4	2.20 ± 1.80	2.12 ± 1.19	0.817
T10	2.35 ± 1.64	2.14 ± 1.40	0.533
T16	2.08 ± 1.79	1.93 ± 1.24	0.675
T30	1.90 ± 2.02	1.85 ± 1.25	0.888

T4: 4 min after the erector spinae plane block; T10: 10 min after the erector spinae plane block; T16: 16 min after the erector spinae plane block; T30: 30 min after the erector spinae plane block. PI ratio: PI at each time point/PI at T0.

Table 3. *Changes to numeric rating scale (NRS) score over time.*

	Responders (n = 59)	Nonresponders (n = 33)	*P*-value
T0	6.1 ± 0.7	5.9 ± 1.2	0.378
T30 min	4.2 ± 1.4	4.6 ± 1.3	0.493
T2 weeks	2.3 ± 1.1	4.5 ± 1.3	<0.001
T4 weeks	1.7 ± 0.7	4.5 ± 1.3	<0.001

T0: before treatment; T30 min: 30 min after the erector spinae plane block; T2 weeks: 2 weeks after the erector spinae plane block; T4 weeks: 4 weeks after the erector spinae plane block.

Table 4. *Changes to neck disability index (NDI) over time.*

	Responders (n = 59)	Nonresponders (n = 33)	*P*-value
T0	14.8 ± 6.3	15.8 ± 4.9	0.464
T4 weeks	8.9 ± 5.1	14.7 ± 5.1	< 0.001

T0: before treatment; T30 min: 30 min after the erector spinae plane block; T2 weeks: 2 weeks after the erector spinae plane block; T4 weeks: 4 weeks after the erector spinae plane block.

Table 5. *Univariate and multivariate logistic regression analyses for predictive factors associated with a successful response after the thoracic erector spinae plane block.*

	Univariate Odds Ratio (95) CI)	*P*-value	Multivariate Odds Ratio (95) CI)	*P*-value
Age	1.04 (0.99-1.08)	0.058		
Body Mass Index	1.13 (0.96-1.33)	0.142		
Pre-Injection Symptom				
Arm pain only	Reference			
Neck and arm pain	0.83 (0.34-2.04)	0.686		
Pain duration (month)	0.94 (0.88-1.01)	0.112	0.94 (0.94-1.91)	0.222
Injection side (left)	1.1 (0.47-2.58)	0.828		
Disease Type				
Foraminal stenosis	Reference			
Herniated disc disease	0.54 (0.19-1.52)	0.243		
Baseline Perfusion Index Perfusion Index (PI) Ratio at 10 Min	1.67 (1.21-2.31)	0.002	1.91 (1.27-2.86)	0.002
PI ratio < 1.5	Reference			
PI ratio 1.5–3	1.14 (0.44-2.96)	0.794		
PI ratio > 3	1.01 (0.32-3.22)	0.983		

In the present study, the location of pain was subdivided into neck pain only, arm pain only, and simultaneous neck pain and arm pain. However, the location of the original pain was not associated with a successful outcome of an ESPB. In contrast to the results of this study, a cervical epidural steroid injection performed in patients who presented with arm pain only was associated with a successful treatment outcome (10).

The PI analyzes peripheral blood circulation, using the wave form obtained from photoplethysmography. Pulsatile and nonpulsatile signals comprise the PI, and they are a numerical value for the ratio between the pulsatile and nonpulsatile blood flow. Pulsatile flow is regulated by vessel tension, preload, and a vasoactive drug, whereas nonpulsatile flow is affected by venous tension and body fluid volume (14,31-33). A successful peripheral nerve block or neuraxial block results in increased peripheral blood flow with a high proportion of the pulsatile signal, which in turn results in an increased PI, providing an objective method for predicting the nerve block's success (32,34). The PI was an earlier, clearer, and more sensitive measurement tool than the increase in skin temperature and demonstrated a quicker response after various interventions (14,31). In this study, the PI ratio at 10 minutes after the ESPB was analyzed at a cutoff value of 1.5 to predict the clinical outcomes. The cutoff PI ratio of 1.5 was used because previous studies suggested that a PI ratio of 1.4 or 1.7 at 10 min demonstrated an excellent sensitivity and specificity for predicting the success of the peripheral block (32,34). However, the PI ratio at 10 minutes after the ESPB was not associated with the clinical outcome. Only a higher baseline PI value was associated with a successful clinical outcome.

During the 30-minute PI measurement period, a PI ratio over 1.5 was maintained in both the responder and nonresponder groups. At T10, both groups showed the peak value of their respective PI ratios. However, no statistical differences between responders and nonresponders were shown at that time point. In contrast to the results of this study, the responder group's PI ratio at 5 minutes after the lumbar transforaminal epidural injection demonstrated a significantly higher value than did the nonresponder group's (15).

Limitations

This study includes several limitations. First, the PI was measured only in the blocked sides of patients' upper extremities. Second, the measurement period of 30 minutes was too short to predict any analgesic effects that the ESPB might have had. A longer period of PI measurement is needed to predict ESPBs' analgesic outcomes. Third, only a small number of patients with nonspinal diseases other than cervical radiculopathy were included. Therefore, it is hard to conclude that the thoracic ESPB has any therapeutic benefits for patients with nonspinal diseases such as complex regional pain syndrome, adhesive capsulitis, and post-thoracotomy pain syndrome.

Conclusion

In conclusion, a successful outcome at 4 weeks after the T2 ESPB was achieved in 64% of patients with cervical radiculopathy. A higher baseline PI value was an independent factor associated with a successful response to a T2 ESPB.

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