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Change in pulse transit time in the lower extremity after lumbar sympathetic ganglion block: an early indicator of successful block

Eun-Young Joo, Yu Gyeong Kong, Jonghyuk Lee, Hyun-Seok Cho, Sung-Hoon Kim and Jeong Hun Suh

Abstract

Objective: To investigate the change in pulse transit time (PTT)—time between the electrocardiographic R wave and the highest point of the corresponding plethysmographic wave—after lumbar sympathetic ganglion block (LSGB) and evaluate PTT as an indicator of successful LSGB.
Methods: Sixteen cases of sympathetically mediated lower extremity neuropathic pain treated with LSGB were studied. Correlations between the changes in PTT and temperature were used to identify the cutoff point indicating successful LSGB.
Results: PTT rate of change at 5 min relative to the baseline PTT (dPTT5/PTT0) significantly correlated positively with the temperature change at 20 min (correlation coefficient 0.734). The dPTT5/PTT0 ratios of the Success and Failure groups were $6.46 \pm 2.81\%$ and $2.77 \pm 1.72\%$, respectively. The dPTT5/PTT0 cutoff indicating successful LSGB, based on receiver operating characteristic curve analysis, was 4.23%.
Conclusion: PTT measurement 5 min after local anesthetic injection was an early, objective indicator of successful or failed LSGB.

Keywords

Pulse transit time, pulse oxymetry, blood flow, lumbar sympathetic ganglion block, sympathetic nerve block, diagnostic technique

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Department of Anesthesiology and Pain Medicine, University of Ulsan College of Medicine, Seoul, Republic of Korea

Corresponding author:
Jeong Hun Suh, Department of Anesthesiology and Pain Medicine, Asan Medical Center, University of Ulsan College of Medicine, 88 Olympic-ro 43-gil, Songpa-gu, Seoul 05505, Korea.
Email: paindrsuh@gmail.com

Introduction

Lumbar sympathetic ganglion block (LSGB) has been used as an effective diagnostic and therapeutic procedure for addressing sympathetically mediated neuropathic pain of the lower extremities.[1] It is achieved via percutaneous injection of local anesthetic around the lumbar sympathetic ganglia and results in temporary sympathectomy.[2] After an LSGB attempt, the success of the procedure can be assessed using various tests, such as skin conductance response, sweat tests, thermography, plethysmography, and laser Doppler.[3–6] These tests, however, may be impractical in a clinical setting because they are resource-intensive and require a time delay for interpretion. Clinically, ipsilateral foot temperature measurement is the most commonly used, effective technique because the temperature at the acral region of the body is largely dependent on blood flow, which is well correlated with changes in skin temperature.[7,8] This procedure, however, can take up to 20 min or more, which increases the cost because of the additional operating room time.

Pulse transit time (PTT) refers to the time it takes for a pulse wave to travel between two arterial sites. Because the speed at which this arterial pressure wave travels is inversely proportional to the resistance of the blood vessel, an increased PTT can reflect increased blood flow resulting from a decrease in arterial resistance.[9,10] We therefore hypothesized that the PTT may increase after successful LSGB because of the decreased arterial resistance due to the sympathetic blockade. Hence, the present pilot study investigated the change in PTT after LSGB and evaluated the usefulness of the PTT change as an early, objective predictor of successful LSGB.

Methods

The institutional review board of Asan Medical Center (Seoul, Republic of Korea) approved the protocol of this study. The need to obtain informed consent was waived as we only retrospectively reviewed recorded data for this study. The study was registered at International Clinical Trial Registry Platform on June 1, 2014 (KCT0000975).

Materials and methods

We reviewed medical data from patients who visited our pain clinic (Asan Medical Center, Seoul, Korea) from January to December 2013. Patients between 20 and 80 years old who underwent unilateral LSGB for diagnosis and/or treatment of sympathetically mediated neuropathic pain of the lower extremities were enrolled. Patients with arrhythmia, those who had vascular or valvular disease, or those on antihypertensive drugs were excluded. Patients whose medical records were incomplete regarding any data to be collected for this study were also excluded.

Each reviewed patient had undergone LSGB according to our standard protocol. Performed under fluoroscopy, the LSGB targeted the lower third of the L2 vertebra or the upper third of the L3 vertebra. Patients were placed in a prone position, and the needle insertion sites were covered in a sterile manner. After identifying the target lumbar vertebra using anteroposterior fluoroscopic imaging, the C-arm was rotated 25°–35° toward the block site to avoid the transverse process during needle passage. Lidocaine (1%) was infiltrated at the needle insertion point, and a curved 21-gauge, 15-cm Chiba needle (US-Cut; OptiMed, Ettingen, Germany) was then advanced toward the anterolateral edge of the target lumbar vertebra under fluoroscopic guidance using the tunnel vision technique. After confirming the needle's position on anteroposterior, lateral, and oblique views and ensuring negative aspiration of blood, we injected contrast dye (Omnipaque 300; GE Healthcare, Shanghai, China) to identify the spreading pattern covering the anterolateral surface of the L2 and L3 vertebrae followed by injection of 8–10 ml of 1% lidocaine.

We noninvasively monitored blood pressure levels, the electrocardiography (ECG) and pulse oximetry results, and the temperature of the ipsilateral lower extremity in all patients. The temperature at the skin surface was monitored using a skin probe (DM 852; Ellab, Copenhagen, Denmark) attached to the middle of the plantar surface of the ipsilateral foot. A pulse oximeter sensor was attached to the great toe of the ipsilateral foot. All values measured by a patient monitor (IntelliVue MP 60; Philips, Eindhoven, The Netherlands) were recorded automatically in real time using an interlocking computer program (IntelliView analyzer, version 1.0; Leomedics, Seoul, Korea). Monitoring began before starting the procedure and continued for 30 min after injection of the local anesthetic. We reviewed the difference in temperature (dT20) between baseline (T0) and 20 min after injection of local anesthetics (T20). LSGB was confirmed to be successful if the dT20 was $>2^{\circ}C$.[11,12]

Saved data were converted to WinDaq files, and the PTT was measured using the WinDaqwaveform browser (DATAQ Instruments, Akron, OH, USA). PTT was defined as the time (in milliseconds) between the time the R wave appeared on ECG and the highest point of the corresponding wave seen on plethysmography.[13] We took the average values of the PTT measured from five consecutive waves. We measured the PTT at baseline (PTT0) and at 1 min (PTT1), 5 min (PTT5), 10 min (PTT10), 20 min (PTT20), and 30 min (PTT30) after injection of the local anesthetic. The differences between PTT0 and each subsequent PTT value (dPTTx) were then determined. The dPTTx/PTT0 ratio was used to detect significant changes after LSGB.

Statistical analyses

The Mann–Whitney U-test and Fischer's exact tests were used to compare data between the groups of patients. Differences in PTT after LSGB relative to the baseline PTT and between groups and were analyzed using repeated-measures analysis of variance.

Correlations between dT20 and dPTT were tested using Spearman's correlation coefficient. Receiver operator characteristic (ROC) curve analysis was used to determine the cutoff point that indicated LSGB success. The ROC curve was constructed using the rate of change in the dPTTx. All statistical analyses were performed using SPSS for Windows, version 21 (IBM Corp., Armonk, NY, USA). A value of $P < 0.05$ was considered to indicate statistical significance.

Results

Among the 24 patients who underwent LSGB from January to December 2013, the 16 patients (11 men, 5 women; ages 39–77 years) who had adequate data for analysis were enrolled. The reasons underlying the need for LSBG in this series included complex regional pain syndrome (n = 6), failed back surgery syndrome (n = 3), spinal stenosis (n = 2), diabetic neuropathy (n = 2), peripheral neuropathy (n = 2), and post-traumatic syndrome (n = 1) (Table 1).

LSGB was successful in nine cases (Success group, 56%) and unsuccessful in seven cases (Failure group, 44%). There were no significant differences between the two groups in regard to sex or sides on which the LSGB was performed (Table 2). The mean PTTx differed statistically significantly between time points ($P < 0.001$), and there were statistically significant differences between the Success and Failure groups as well ($P = 0.005$). The mean PTT values for each group are shown in Figure 1.

Table 1. Demographic characteristics of the study patients

Variable	Values (n = 16)
Sex (male/female)	11/5
Age (years)	59 ± 14
Diagnosis	
Complex regional pain syndrome	6 (37.5)
Failed back surgery syndrome	3 (18.7)
Spinal stenosis	2 (12.5)
Diabetic neuropathy	2 (12.5)
Peripheral neuropathy	2 (12.5)
Post-traumatic syndrome	1 (6.3)

Data are the mean ± SD (range) or number (percentage) of patients.

Table 2. Comparison of the characteristics of successful and unsuccessful LSGB procedures

Variable	dT20[a] ≥ 2 (n = 9)	dT20[a] < 2 (n = 7)	Statistical significance
Sex (male/female)	7/2	4/3	NS[d]
Side of LSGB (right/left)	5/4	3/4	NS[d]
dPTT5[b]/PTT0[c] (%)	6.46 ± 2.81	2.77 ± 1.72	P = 0.006

LSGB, lumbar sympathetic ganglion block; PTT, pulse transit time.
Data are the mean ± SD or number of patients.
[a]Difference in temperature 20 min after injection of local anesthetic.
[b]Difference in pulse transit time 5 min after injection of local anesthetic.
[c]Pulse transit time at baseline.
[d]NS, not statistically significant ($P > 0.05$).

The correlation analysis showed that dPTT5/PTT0 and dPTT20/PTT0 were significantly correlated with dT20 (Spearman's rho 0.734 and 0.617, respectively; $P = 0.001$ and 0.011, respectively) (Figure 2). The dPTT5/PTT0 and dPTT20/PTT0 of the Success group were 6.46 ± 2.81% and 7.17 ± 3.62%, respectively, whereas those of the Failure group were 2.77 ± 1.72%

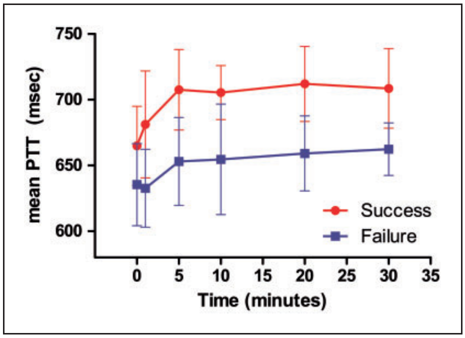

Figure 1. Average pulse transit time (PTT) at baseline and after the procedure in the Success and Failure groups.

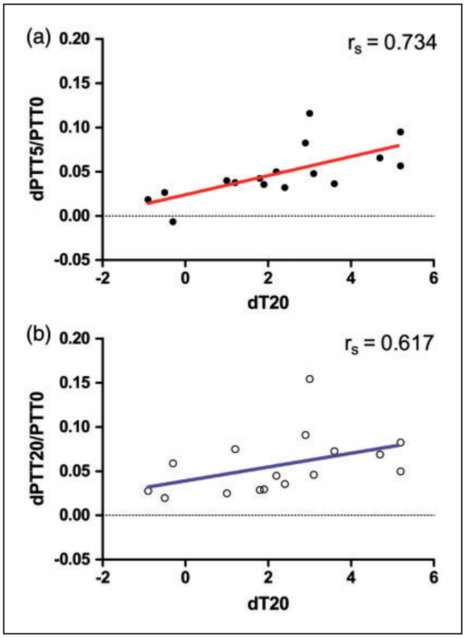

Figure 2. Correlation analysis of the change in temperature at 20 min with the ratio of the difference in pulse transit time (PTT) at baseline to that at 5 min (a) and 20 min (b). Correlation coefficients were determined with Spearman's rank correlation analysis. dT20, difference in temperature 20 min after injection of local anesthetic; PTT0, PTT at baseline; PTT5 and PTT20, PTT 5 and 20 min after injection of local anesthetic.
dPTTx = PTTx – PTT0; rs, Spearman's rho

Table 3. Sensitivity and specificity of each cutoff point of the rate of variance in pulse transit time at 5 min compared with that at baseline

dPTT5[a]/PTT0[b] (%)	Sensitivity (%)	Specificity (%)
3.98	77.8	85.7
4.23[c]	77.8	100
4.78	66.7	100
4.98	55.6	100
5.66	44.4	100
6.56	33.3	100

PTT = pulse transit time.
[a]Difference in pulse transit time 5 min after injection of local anesthetics.
[b]Pulse transit time at baseline.
[c]Best cutoff point on the receiver operating characteristic curve.

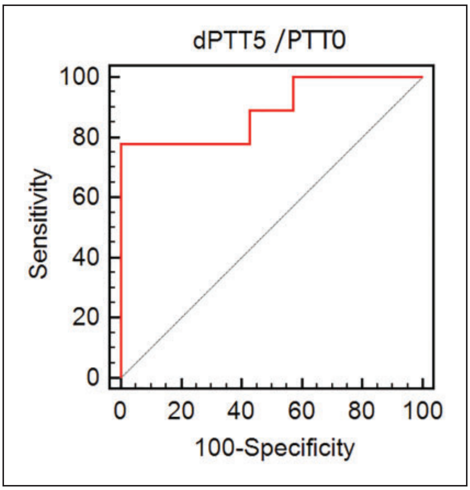

Figure 3. Receiver operating characteristic (ROC) curve of the ratio of the difference in pulse transit time (PTT) at 5 min after injection of local anesthetic compared with that at baseline.

and 3.78 ± 2.07%, respectively. These differences were statistically significant ($P = 0.006$ and 0.023, respectively) (Table 2). The cutoff point of dPTT5/PTT0 for successful LSGB was estimated from an ROC curve analysis, with the best value being 4.23% (sensitivity 77.8%, specificity 100%) (Table 3, Figure 3).

Discussion

We investigated the changes in PTT in patients who had undergone LSGB to alleviate pain in the lower extremities. We believed that such changes would indicate, by the magnitude of the PTT change, whether the LSGB had been successful. In the present study, the PTT of the ipsilateral foot was significantly prolonged 5 min after injection of the local anesthetic in cases of successful LSGB. The cutoff ratio of the change in PTT at 5 min that verified a successful LSGB was 4.23%.

Although LSGB has been widely used for the diagnosis and treatment of sympathetically mediated pain of the lower extremities, the diagnostic value or treatment effect has not been clearly established. This is because of the variability of the sympathetic component, which contributes to pain relief as well as to a placebo effect, can confound the treatment effects.[14,15] Hence, there have been many efforts to improve the outcome of complete LSGB, such as increasing the accuracy of both the localization of the sympathetic ganglia and placement of the local anesthetic.[16] Monitoring the response to LSGB has been another important issue because, in the case of incomplete LSGB, it allows clinicians to readjust or add more local anesthetic within a reasonable amount of time.[12,17,18]

For that reason, recent studies have focused on earlier prediction of successful LSGB. Schmid et al.[18] monitored the sympathetic skin response at 6–7 min after drug injection as an early indicator of LSGB success. Park et al.[12] measured the rate of change in skin temperature and reported that LSGB was considered successful if the rate of change reached more than 2°C/min within 5 min after drug injection. As indicated by the results of the current study, the measurement of PTT at 5 min after local anesthetic injection helps determine successful LSGB quickly. It saves time and improves the efficacy of operating room usage. In a university hospital setting with a residency training setting, saving time is particularly important because block procedures may be time-consuming. Kortekaas et al.[24] previously emphasized measuring the pulse transit time after axillary nerve block.

Various measurements for verifying successful LSGB have been introduced, such as a sweat test, sympathogalvanic response, thermography, plethysmography, and laser Doppler flowmetry.[3–6,19] These tests, however, are not readily available to clinicians because they are resource-intensive and result in additional medical costs to the patients as well as additional time for interpretion. Monitoring the changes in skin temperature is another method for evaluating sympathetic block.[3,7,20,21] Because body temperature is largely dependent on blood flow, sympatholysis could be measured in terms of the increase in temperature of the ipsilateral extremity after a sympathetic block. Skin temperature measurement is inexpensive and painless, so it has been commonly used to evaluate sympathetic blocks in most busy clinical settings. Skin temperature, however, is influenced by the surrounding environment. In addition, there are still conflicting opinions on the timing of the temperature assessment. It was reported that a skin temperature measurement is required to verify ipsilateral sympathicolysis at least 90 min after the intervention.[22]

Compared with these monitoring methods, the PTT measurement for assessing LSGB objectively is inexpensive, rapid, and safe. PTT measurement requires only ECG and pulse oximetry, which are basic, noninvasive monitoring devices used during LSGB. Sympathetic blockade changes arterial compliance via vasodilation and leads to decreased pulse wave velocity.[4,9,10,23] Hence, arterial compliance can be measured indirectly by measuring the PTT of blood that flows from a fixed distance away from the blood vessel. Babchenko et al.[23] previously measured an increase in PTT to the feet after epidural anesthesia, and Kortekaas et al.[24] showed that the PTT to the finger is a reliable predictor of successful axillary brachial plexus block. Because arterial compliance can be displayed in various ways, depending on the conditions of the heart and arteries in the individual patient,[25] the absolute values of PTT cannot be compared among individuals. For this reason, we measured the differences in PTT after LSGB and compared them between success and failure of LSGB using the ratio of the PTT change to the baseline PTT, rather than using the absolute PTT value. In our study, the PTT ratio differences from baseline to that at 5 and 20 min showed positive correlations with the change in temperature at 20 min. The data were significantly different between the LSGB Success and Failure groups.

A limitation of our study was the small number of patients ($n = 16$). The results of our pilot study, however, indicated the potential usefulness of PTT for assessing the success of LSGB. Now, a larger, well-controlled study is needed to investigate this relation more extensively and to establish a cutoff value for predicting successful LSGB. Although the PTT is conveniently measured using ECG and pulse oximetry, the absence of software that automatically calculates the PTT was another limitation. As a result, when measuring PTT with ECG and pulse wave technology, artifacts may appear because of patient movement. Furthermore, the subjective selection of the plethysmographic pulse wave causes bias when measuring PTT. Therefore, we defined PTT as the time between the R wave on ECG and the peak of the corresponding pulse wave on plethysmography. One researcher was responsible for the PTT measurements, with PTT being represented as the average of five PTTs measured from five consecutive waves.

To our knowledge, the present study has uniquely evaluated the effect of LSGB on changes in the PTT. The results of our current study showed that the measurement of PTT 5 min after local anesthetic injection can help verify successful LSGB as a noninvasive, safe, easy-to-use, rapid, objective technique. It could save clinicians time instead of waiting for the changes in temperature, meaning that they can make a more timely decision regarding the need for additional LSGB. Consequently, it could improve the diagnostic and therapeutic ability of LSGB to alleviate sympathetically mediated neuropathic pain of the lower extremities. In addition, the future development of software for automatic calculation of the PTT with standard ECG and standard pulse oximetry with a commonly used monitor will be mandatory for allowing PTT to be used as a widely available tool. It will be an easy-to-use, noninvasive, safe, rapid method for objectively assessing the success of LSGB.

Declaration of conflicting interest

The authors declare that there are no conflicts of interest.

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