석 사 학 위 논 문

The Analysis of Trends of Perfusion Index and Plethysmographic Variability Index during Elective Cesarean Section

계 명 대 학 교 대 학 원

의 학 과

하 나 정

지도교수 홍 지 희

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하 나 정

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지도교수 홍 지 희

이 논문을 석사학위 논문으로 제출함

2021년 2월

계 명 대 학 교 대 학 원

의학과 마취통증의학 전공

하 나 정

하나정의 석사학위 논문을 인준함

주 심 박 기 범

부 심 홍 지 희

부 심 박 지 훈

계 명 대 학 교 대 학 원

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하 나 정

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1. Introduction

Spinal anesthesia is commonly performed for Cesarean section, as it has many advantages over general anesthesia. But it carries a risk of hypotension which may cause some adverse effects such as nausea, vomiting, dizziness in parturients, and umbilical arterial acidosis in the newborn [1,2].

Hypotension following spinal anesthesia is mainly caused by peripheral vasodilatation and sympathetic blockade [3,4]. Peripheral vasodilatation causes venous pooling of extremities, which results in decrease of preload [5,6]. Predicting a risk of hypotension is essential to minimize an adverse effect of the parturient and the newborn. Although management with vasoactive drugs and intravascular volume loading maintains hemodynamic stability, hypotension may not be completely avoided because of the lag in non-invasive blood pressure monitoring.

Baseline peripheral vasomotor tone, volume status, and sympathetic activity are known to affect the degree of hypotension after spinal anesthesia in parturients undergoing Cesarean section [5,6]. Dynamic indices, such as stroke volume variation, pulse pressure variation, perfusion index (PI), and plethysmographic variability index (PVI) are known to be better predictors of fluid responsiveness and hypotension than static indices in mechanically ventilated patients [7,8]. Among these, PI and PVI are novel markers that can be measured non-invasively and automately from the pulse oximetry waveforms.

The PI derived from a pulse oximeter is calculated as the ratio of the pulsatile blood flow to the non-pulsatile blood in the peripheral tissue and can be used to assess peripheral perfusion differences due to changes in the peripheral vascular tone. The PI is calculated using

direct current which indicates an amount of light constantly absorbed by skin, non-pulsatile blood and other tissues and alternate current which is a variable amount of light absorbed by pulsating arterial flow. The PI measured by pulse oximetry reflects patient's vasomotor tone and a lower PI indicates greater peripheral vasomotor tone [3,4].

$$PI = (\text{Alternant current} / \text{Direct current}) \times 100$$

PVI is calculated using maximum and minimum values of PI during respiratory cycles. A higher PVI values reflect larger respiratory fluctuation of the PI values, and may indicate greater fluid responsiveness.

$$PVI = \{(\text{Maximum of PI} - \text{minimum of PI}) / \text{Maximum of PI}\} \times 100$$

In previous studies, both PI and PVI had been reported as good predictors of hypotension in parturients during Cesarean section under spinal anesthesia. Baseline PI over 3.5 and PVI measured after spinal anesthesia over 18% could predict the incidence of spinal anesthesia-induced hypotension during Cesarean section [6,9,10].

Our hypothesis of this study was that the trends of PI and PVI values in parturients who developed hypotension would demonstrate different trends compared to parturients without hypotension. The primary endpoint of this study was to analyze the trends of PI and PVI between hypotension and normotension groups during Cesarean section following spinal anesthesia.

2. Material and Methods

After getting approval of the study by the Institutional review board (Keimyung University Dongsan Hospital, IRB No. 2020-06-040), parturients undergoing Cesarean section between June, 2020 and September, 2020 were enrolled. Written informed consent was obtained from each parturients in the study.

Parturients aged from twenty to forty with single tone or twin pregnancy who are scheduled for elective cesarean section were recruited. We excluded parturients with emergency cases, cardiovascular or cerebrovascular disease, placenta previa, preeclampsia, morbid obesity with BMI $\geq$ 40, gestational age 34 or 40 weeks, and contraindications to spinal anesthesia.

2.1 Study protocol

On arrival of operating room, each parturients was laid on an operating table and was given an infusion of 300 mL of Plasmalyte solution (Baxter, S.L) for prehydration. No premedication was given to the parturient and the temperature of the operating room was maintained at 22 ℃. Electrocardiography (ECG), Noninvasive blood pressure (NIBP), Pulse oximetry (Masimo Radical 7; Masimo Corp., Irvine, CA, USA) were applied. A pulse oximetry probe was placed on the left 4^{th} finger.

Every parturients had 3 minutes of resting period in supine position to minimize the variation of baseline PI value. After 3 minutes of resting period, baseline systolic blood pressure (SBP), diastolic blood pressure

(DBP) and mean blood pressure (MBP), heart rate (HR), PVI and PI were measured. And then spinal anesthesia was done with 0.5% hyperbaric bupivacaine (10 mg) and Fentanyl (15 μg) at the L3-4 intervertebral space using 25 G-whittacre needle. Blood pressures, HR, PVI and PI values were measured in the sitting position. After returning to supine position, a wedge pillow was placed underneath the right buttock to avoid aortocaval compression to facilitate the uterine blood supply.

The upper sensory block level was assessed 5 minutes after spinal anesthesia by loss of cold sensation using alcohol swabs. If sensory block at the T6 level was not achieved by 10 minutes after spinal anesthesia, the patient was excluded from the study.

Plasmalyte solution was rapidly administered at a rate of 20 mL/min. The data of blood pressure, HR, PVI, and PI values were collected from the induction of spinal anesthesia until delivery of baby with one minute interval.

2.2 Group allocation

The parturients were divided into two groups according to whether they developed hypotension (hypotension group) or maintained normal blood pressure (normotension group) after spinal anesthesia. Hypotension was defined as a decrease of MBP < 60 mmHg or decrease more than 25% compared to baseline value. This definition was applied according to the result of a previous study [2]. When hypotension occurred, phenylephrine 100 μg was injected. Every Cesarean section was done by one surgeon.

2.3 Statiscal Analysis

Patient demographic data were presented as mean (SD) or median (range) and were analyzed by Student's t-test, Chi-squared test, as appropriate. The perioperative hemodynamic parameters, PI, and PVI were assessed by Student's t-test.

For all analysis, statistical significance was defined as $P < 0.05$. The SPSS version 22.0 (IBM Corporation, Armonk, NY) was used for statistical analysis.

3. Results

Fifty-seven parturients were enrolled in the study. Among them, six parturients were excluded from the study because their level of sensory block was inadequate for the surgery. Therefore, this analysis was performed with fifty-one parturients (Fig. 1).

Hypotension occurred in 61% of parturients during the surgery. Thirty-one parturients developed hypotension during Cesarean section, while the remaining twenty parturients without hypotension. Hence, those thirty-one parturients who developed hypotension were assigned to hypotension group.

Demographical characteristics of parturients were compared between two groups (Table 1).

Hemodynamic values of two groups before and after spinal anesthesia were compared. Baseline hemodynamic values were not significantly different from each other. However, minimum blood pressure after spinal anesthesia demonstrated significant differences between two groups (P = 0.005, Table 2).

The overall value of PI after spinal anesthesia has gradually increased in both groups. Baseline PI value of normotension group was higher than that of hypotension group. PI values of both groups decreased when the position of parturient was changed from supine to sitting. From 7 minutes after induction of spinal anesthesia, PI value of hypotension group started to demonstrate higher than normotension group and such trend was maintained until final delivery of the baby.

However, the difference of PI values between two groups was not significant during whole period of PI measurement (Fig. 2).

Immediately after spinal anesthesia, the PVI value increased in both

group and then it gradually decreased until delivery of the baby. The PVI values of hypotension group were greater than that of normotension group, except a few minutes after the induction of anesthesia (Fig. 3).

Table 1. Demographic data

	Normotension group (n=20)	Hypotension group (n=31)	P-value
Age (years)	35 ± 4.7	34.8 ± 4.6	0.90
Gestational age (weeks)	37.1 ± 1.6	37.1 ± 1.3	0.85
Gestational diabetes	3(15)	1(3.3)	0.29
Twin pregnancy	5(25)	11(35.5)	0.54
Height (cm)	162.6 ± 4.2	162.1 ± 6.2	0.79
Weight (kg)	74.6 ± 15.5	71 ± 8.7	0.30
BMI (kg/m^2)	28.1 ± 6	27.2 ± 3.5	0.48

Values are presented as mean ± SD or number of cases (percent).

BMI: Body mass index.

Table 2. Hemodynamic data in patients before and after spinal anesthesia

		Normotension group (n=20)	Hypotension group (n=31)	P-value
Baseline hemodynamic data	SBP (mmHg)	122.6 ± 9.5	126.5 ± 17.8	0.31
	DBP (mmHg)	68.2 ± 8.6	74.1 ± 12.4.	0.07
	MBP (mmHg)	89.2 ± 7.8	90.1 ± 20.3	0.83
	HR (bpm)	75.1 ± 13.3	81.1 ± 13.9	0.13
Minimum Blood Pressure (mmHg)	SBP	100.1 ± 8	85.9 ± 13	< 0.001
	DBP	51.5 ± 5.1	44.9 ± 8.8	< 0.001
	MBP	72.3 ± 5.6	61.1 ± 10.4	< 0.001
Mean Blood Pressure (mmHg)	Before spinal anesthesia	89.2 ± 7.8	90.1 ± 20.3	0.83
	Sitting	94.8 ± 11.6	94 ± 14.4	0.84
	After spinal anesthesia	84.3 ± 12.5	78.8 ± 17.1	0.83
	Start of surgery	81.1 ± 11.1	76.3 ± 11.4	0.22
	Delivery	77.6 ± 9.4	72.5 ± 9.3	0.19
Heart rate (bpm)	Before spinal anesthesia	75.1 ± 13.3	81.1 ± 13.9	0.13
	Sitting	79.3 ± 17.8	84.5 ± 14.2	0.13
	After spinal anesthesia	76.4 ± 13.6	81.5 ± 16.8	0.25
	Start of surgery	75.1 ± 14.7	79.7 ± 14.1	0.28
	Delivery	82 ± 13.8	83 ± 16.3	0.25

Values are presented as mean ± SD. DBP: diastolic blood pressure; MBP: mean blood pressure; SBP: systolic blood pressure.

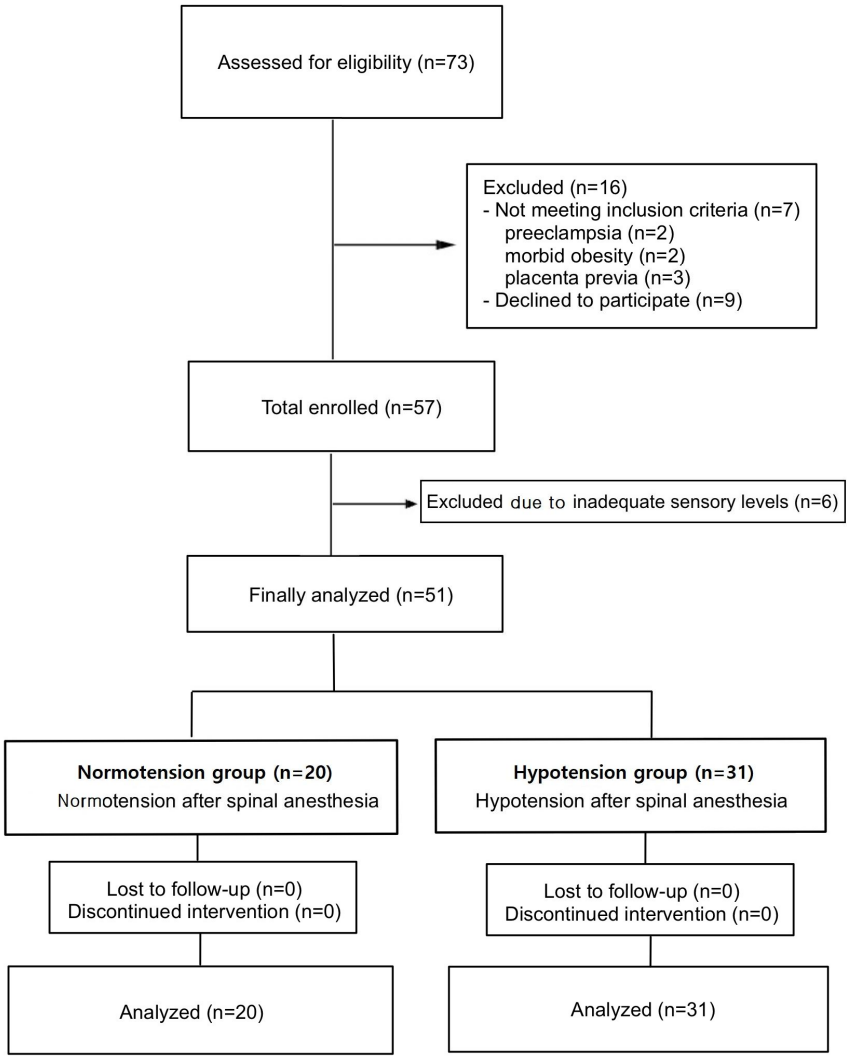

Figure 1. Flow chart of the study.

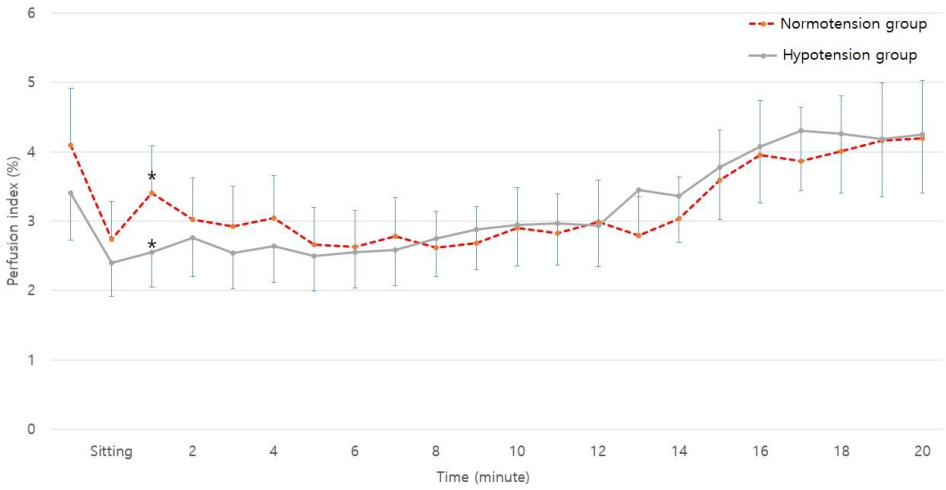

Figure 2. Changes of perfusion index (%) in normotension and hypotension group.

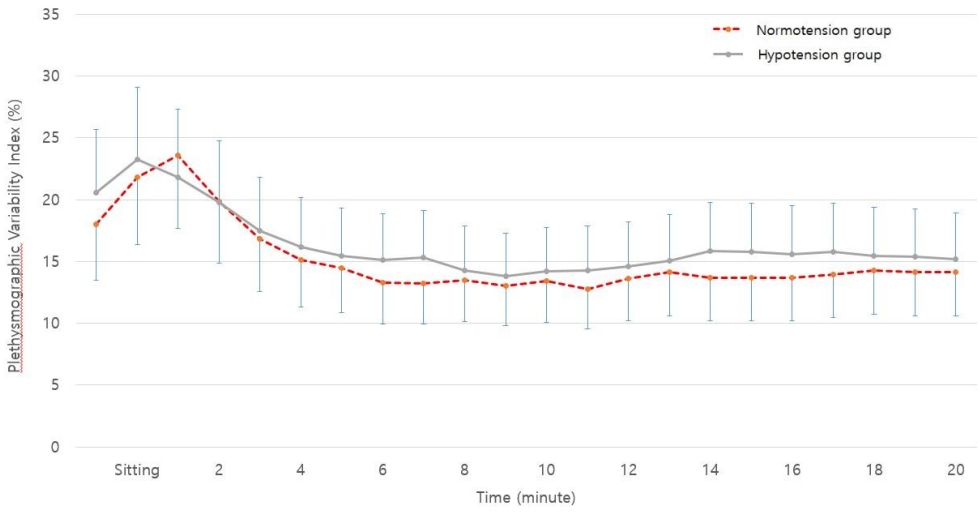

Figure 3. Changes of plethysmographic variability index (%) in normotension and hypotension group.

4. Discussion

In this prospective study, the results showed that the overall trends of PI and PVI in both groups were gradually increased and decreased, respectively. However, there was no significant differences in PI and PVI values between two groups after spinal anesthesia.

Spinal anesthesia causes sympathetic blockade in the affected lower extremities [3]. It causes the decreased systemic vascular resistance, blood pooling in the blocked area, leading to reductions of cardiac output and mean blood pressure.

Normal physiologic changes of third trimester of pregnancy include decrease in systemic vascular resistance, increase of blood volume, stroke volume, heart rate, and cardiac output. Because of pregnancy-induced decrease in vascular tone, parturients have more blood volume trapped in extremities, and have higher PI and PVI values than non-parturients [1].

Previous studies showed that higher baseline PI and PVI values have an ability to predict the hypotension after the spinal anesthesia for Cesarean section [6,9]. Greater PVI value after spinal anesthesia is also associated with incidence of hypotension [10]. According to the previous studies, the baseline PI and PVI values of hypotension group were expected to be higher than that of normotension group. Our study showed a higher baseline PVI values in hypotension group, whereas higher baseline PI values in normotension group.

The increased PVI value immediately after spinal anesthesia was an independent risk factor of spinal anesthesia-induced hypotension [10].

This study also showed increased PVI value immediately after spinal anesthesia. However, the degree of increase was higher in normotension

group than hypotension group. Kuwata et al [10]. suggested optimal PVI threshold of 18% to predict hypotension after spinal anesthesia. However, in this study, the PVI value of hypotension group was maintained less than 18% until delivery of baby except for 3 minutes immediately after induction of spinal anesthesia.

Contrary to the study by Toyama et al [6]. which demonstrated higher PI value at baseline to predict hypotension, our study showed lower PI value in hypotension group from baseline to 7 minutes than normotension group and then it was reversed. In this study, the pulse oximetry probe was placed on left 4th finger of the parturients.

Therefore, PI values can represent the vasomotor changes of upper extremities. We suppose that lower PI value of hypotension group from baseline to 7 minutes after spinal anesthesia is due to the difference of uppermost level of sensory block between two groups. In former studies, high thoracic sensory block (C7-T3) induced thoracic sympathetic block that proceeds and exceeds sensory block [11,12]. Ginosar et al [5]. have demonstrated that an increase in PI value was an earlier and more sensitive indicator of the development of epidural induced sympathectomy compared with an increase in skin temperature. We suppose that uppermost level of sensory block from spinal anesthesia was lower in hypotension group than normotension group immediately after spinal anesthesia. Such lower level of sensory block in hypotension group resulted in an increased vasomotor tone of upper extremity compared to normotension group, leading to lower PI value. However, after 7 minutes, hypotension group might become similar or even higher sensory level compared to normotension group since PI started to show higher than normotension group.

According to the conflicting result of our study, overall application of PI and PVI value to predict hypotension has some limitations and it

requires further study.

In our study, 61% of parturients developed hypotension after spinal anesthesia. This is in consistency with former studies under the same definition of hypotension (59.3%) [2]. The incidence of hypotension during spinal anesthesia for Cesarean section varies, ranging from 7.4% to 74.1% [2]. We think that this variation results from the definition of hypotension which was used during their study.

Our study has several limitations. First, photoplethysmographic analysis is sensitive to emotional stress, anxiety, and movement of the patient. Although all parturients in this study had 3 minutes of resting period to minimize such emotional factor, the resting period of 3 minutes might be too short to remove emotional factor entirely. Second, PVI may be less accurate in evaluation of intravascular volume and prediction of fluid responsiveness in spontaneously breathing patients, which may be partially related to the greater changes in respiratory rate and tidal volume. Third, physiologic conditions vary between patients, therefore, PI may be considered a relative number which reflects the change trends rather than an absolute number. Fourth, we did not check the uppermost level of sensory block, but we only checked whether the sensory loss reached to T6 dermatome or not.

In conclusion, we demonstrated that the trend of PI value has gradually increased while the PVI value has decreased, regardless of whether the parturient has experienced hypotension or not. Further studies using PI and PVI values should be conducted to assess the effect of hemodynamic variations in spinal anesthesia for Cesarean section.

5. Summary

Spinal anesthesia is commonly performed for Cesarean section, as it has many advantages over general anesthesia. However, it carries a risk of hypotension. Hypotension following spinal anesthesia is mainly caused by peripheral vasodilation and venous pooling due to sympathetic blockade. The degree of sympathetic activity is known to affect the occurrence of hypotension after spinal anesthesia for cesarean section. The Perfusion Index (PI) and Plethysmographic Variability Index (PVI) are non-invasive tools for measuring the vasomotor tone and volume status. The purpose of this study is to observe the trend of PI and PVI during cesarean section under spinal anesthesia and to investigate whether the PI and PVI measured before/after spinal anesthesia could predict hypotension during the surgery.

Fifty-one parturients undergoing elective cesarean section with hyperbaric bupivacaine 10 mg and Fentanyl 20 μg were enrolled in this study. The trend of PI and PVI during the surgery and the incidence of hypotension were investigated.

Hypotension occurred in 61% of parturients during the surgery. The overall PI and PVI value after spinal anesthesia has gradually increased and decreased, respectively. The degree of increase and decrease in PI and PVI value was not significant between groups of hypotension and normotension. The trend of PI value has gradually increased while the PVI value has decreased, regardless of whether the parturient has experienced hypotension or not.

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The Analysis of Trends of Perfusion Index (PI) and Plethysmographic Variability Index (PVI) during Elective Cesarean Section

Ha, Na Jeong

Department of Anesthesiology and Pain medicine
Graduate School

Keimyung University

(Supervised by professor Hong, Ji Hee)

(Abstract)

Hypotension following spinal anesthesia of Cesarean section is mainly caused by peripheral vasodilation and venous pooling due to sympathetic blockade. The degree of sympathetic activity is known to affect the occurrence of hypotension after spinal anesthesia. The perfusion index (PI) and plethysmographic variability index (PVI) are non-invasive tools for measuring the vasomotor tone and volume status. The purpose of this study is to compare the trends of PI and PVI values between hypotension and normotension groups during cesarean section following spinal anesthesia. Fifty-one parturients were divided into two groups whether they developed hypotension or maintained normotension after spinal anesthesia. Spinal anesthesia was performed with 0.5% hyperbaric bupivacaine (10 mg) and fentanyl (15 μg) at the L3-4 intervertebral

space. The data of blood pressure, heart rate, PI and PVI were recorded every minute until delivery of baby. Hypotension occurred in 61% of parturients during Cesarean section. The overall PI and PVI value after spinal anesthesia have gradually increased and decreased, respectively. The degree of increase and decrease in PI and PVI value was not significant between hypotension and normotension groups. The trend of PI value has gradually increased while the PVI value has decreased, regardless of whether the parturient has experienced hypotension or not.

척추마취 하 제왕절개에서의 Perfusion Index 및 Plethysmographic Variability Index의 경향성 분석

하 나 정
계명대학교 대학원
의학과 마취통증의학 전공
(지도교수 홍 지 희)

(초록)

척추마취는 정규 제왕절개 수술 시행 시 마취방법의 선택에 있어 태아에 대한 마취제의 영향에서 비교적 자유롭고 술 후 통증조절이 용이하다는 점 등의 장점으로 전신마취보다 선호된다. 하지만 술 중 저혈압이 발생할 경우 구역, 구토 등의 부작용과 더불어 태아의 제대혈산증 등을 유발할 수 있어 마취 전중후로 적절한 모니터링 및 혈압 관리가 필요하다. 이 연구에서는 51명의 산모를 대상으로 척추마취 후 제왕절개 도중 저혈압의 발생 여부 및 정상혈압군과 저혈압군의 PI와 PVI의 경향성을 각각 분석하였다. 그 결과 61%의 산모에서 저혈압이 발생하였고 술 중 PI, PVI 증감 정도에서는 정상혈압군, 저혈압군 간의 큰 차이가 없었으나, 전반적으로 두 군 모두에서 PI는 증가, PVI는 감소 양상을 보였다.