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Is the Perfusion Index Useful in Early Detection of High Spinal Subarachnoid Block during Cesarean Section ?

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Objective: To investigate the usefulness of the perfusion index (PI) in the early detection of high spinal subarachnoid block (SAB) for cesarean section (CS).
Method: SAB was applied in patients of CS . The patients was subdivided into two groups, according to the highest level of block : the Ce group (cervical spine level) and the Th group (thoracic spine level). The PI values in the finger and toe, and vital signs were measured at pre- and post-SAB in both groups together with SAB level.
Results: The PI valuses in the finger and toe were elevated post-SAB in both groups; it showed no significant difference between them. However, in the Ce group, anesthesia immediately reached the upper thoracic nerves, and blood pressure showed a significant decrease post-SAB.
Conclusions: Post-SAB finger PI value measuerments may not be useful for early detection of high SAB. Alternatively, the anesthesiologist should pay attention to immediate post-SAB changes in clinical signs such as a decrease in blood pressure as well as a rapid elevation of block level.

Key words: cesarean section, subarachnoid block, perfusion index

INTRODUCTION

The perfusion index (PI) is obtained by pulse oximetry and provides a numeric value indicating the ratio of pulsatile components (arterial blood) to non-pulsatile components (flow of venous and tissue blood) in the pulse wave. The PI is correlated with change in blood flow in the fingertip [1]. In the field of anesthesia for obstetric procedures, there have been sporadic reports of change in the PI with spinal subarachnoid block (SAB) for cesarean section (CS) [2, 3]. Application of SAB for cesarean section (CS) sometimes results in block of the cervical nerves, which include the phrenic nerve (C4). There is a risk of respiratory depression occurring if the phrenic nerve is blocked, indicating the importance of detecting cervical nerve block as quickly as possible. We have encountered elevation of PI in a clinical setting when cervical nerve block occurred. To our knowledge, no studies to date have investigated early detection of cervical nerve block. The purpose of this study was to investigate the usefulness of the PI in the early detection of high SAB during CS.

MATERIAL AND METHODS

Patients

Patients undergoing obstetric or gynecological surgical procedures were enrolled in the study. All the patients had an ASA-PS (ASA-physical status) of 1–2.

Spinal subarachnoid block was selected as the anesthetic method in all procedures. Pregnant patients scheduled for emergency procedures and those categorized as high risk (> 4 points) were excluded from the evaluation. The patients were divided into a conization (Con) group and a CS group. The CS group was further divided into two groups according to the highest level of block: the Ce group (cervical spine level) and the Th group (thoracic spine level).

Patient background

The patient background in each group is shown in Tables 1 to 3. The Con group included one non-pregnant woman (Table 1). The CS groups are listed separately. In the CS group, evaluation of high risk pregnant women (Table 2) and obstetric problems were also described (Table 3).

Method

The following items were measured in each group: 1) the PI value in the finger and toe at pre- and post-SAB; 2) vital signs (blood pressure, heart rate, and SpO2) at pre- and post-SAB; 3) anesthesia level at pre- and post-SAB; 4) presence or absence of use of vasopressors; and 5) presence or absence of clinical symptoms (nausea and vomiting, numbness of the hand, and respiratory discomfort). After entering the operating room, a pulse-oximeter (Masimo corp/Radical ™) (Fig. 1) probe was attached to the patient's left finger and toe. The control value was defined as the PI value

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Table 1 Patients background in the Con group

	Age	Height (cm)	Weight (kg)	Hb (g/dl) (11.3 to 15.2)	Plt (/mm^3) (13.0 to 36.9 × 10^4)	PT-INR (0.9 to 1.1)
Con group	32 (28–36)	156.3 ± 4.4	52.0 ± 6.3	13.2	22.4 × 10^4	0.99

Age: average value (minimum value - maximum value)
Height, weight: mean ± standard error
Hb, platelet, coagulation, gestational age: mean value

Table 2 Obstetric background in the Th and Ce groups

	High risk classification	Number of pregnancies	Birth number	Gestational age
Th group	2(all)	1(2)/2(1)/3(3)	0(2)/1(1)/2(3)	37W
Ce group	1(1)/2(5)	1(5)/2(0)/3(1)	0(all)	37W

the number in parentheses indicates number of patients.

Table 3 Patients background in the Th and Ce groups

	Age	Height (cm)	Weight (kg)	Hb (g/dl) (11.3 to 15.2)	Plt (/mm^3) (13.0 to 36.9 × 10^4)	PT-INR (0.9 to 1.1)
Th group	35 (31–39)	156.1 ± 4.4	67.5 ± 6.1	10.8	23.4 × 10^4	0.99
Ce group	33.5 (27–39)	156.1 ± 6.8	59.2 ± 7.3	10.9	22.3 × 10^4	0.97

Age: average value (minimum value - maximum value)
Height, weight: mean ± standard error
Hb, platelet, coagulation, gestational age: mean value

Fig. 1 The pulse-oximeter screen used during the experiments is shown.
← : The PI value obtained is shown

in the finger and toe and vital signs (blood pressure, heart rate, and SpO_2) at pre-SAB. In the Con group, subarachnoid puncture was performed at L3/4 and 2.0–2.2 ml of 0.5% Bupivacaine injected into the subarachnoid space. In the CS group, epidural puncture was performed at L1/2 and the catheter inserted into the epidural space. Subarachnoid puncture was then performed at L3/4 and 1.8 ml of 0.5% Bupivacaine injected into the subarachnoid space. The anesthesia level was investigated in each patient by using the cold test. The average level of anesthesia was also determined in each group. The PI value in the finger and toe and vital signs (blood pressure, heart rate, and SpO_2) at post-SAB were recorded at 2-min intervals. At post-SAB, vasopressors (ephedrine) were injected when systolic blood pressure fell below 80 mmHg. The results are given as the mean and standard error of the mean (S.E.M.) of the data. Statistical analysis was done with two-way repeated measures analysis of variance (ANOVA) or Kruskal-Wallis test, followed by the Dunn's multiple comparison test, where appropriate, as described in figure legends. This study was approved by the Ethics Committee of the Institutional Review Board (IRB) for Clinical Research at Tokai University School of Medicine (14R-200). Informed consent was obtained in compliance with the Helsinki Declaration. Patient anonymity was preserved.

RESULTS

The results for the PI value in the finger and toe, and vital signs (blood pressure, heart rate, and SpO_2) at pre- and post-SAB in the Con group are shown in Fig. 2. The PI values in the toe showed immediate elevation at post-SAB, and were still significantly higher than those at pre-SAB from 12 min post-SAB. On the other hand, the PI value in the finger showed no significant difference to that in the controls. A comparison of the PI values revealed that the PI value in the toe was higher than that in the finger from 4 min post-SAB (Fig. 2: upper). Diastolic blood pressure showed lower values from 26 min post-SAB (Fig. 2: middle). Heart rate and SpO_2, however, were almost stable (Fig. 2: lower). The results for the PI value in the finger and toe and vital signs (blood pressure, heart rate, and SpO_2) at pre- and post-SAB in the Th group are shown in Fig. 3. The PI value in the toe was significantly higher than that in the controls from 8 min post-SAB. The PI value in the finger varied slightly post-SAB, but showed no significant change compared with the control value. A comparison of the PI values revealed a significant difference at time zero and after 22 min post-SAB (Fig. 3: upper). Blood pressure showed no significant difference compared with that in the controls (Fig. 3: middle). Heart rate and SpO_2 were stable (Fig. 3: lower). The results for the PI value in the finger and toe and vital signs (blood pressure, heart rate, and SpO_2) at pre-and post-SAB in the Ce group are shown in Fig. 4. The PI value in the toe was significantly higher than that in the controls from 18 min post-SAB. The PI value in the finger was significantly higher than that in the controls from 12–18 min post-SAB. A comparison of the PI values revealed no significant difference between that in the finger and toe, with both values showing an upward trend compared with the control value (Fig. 4: upper). Blood pressure (systolic and diastolic) showed an immediate and significant decrease post-SAB (Fig. 4: middle). Heart rate showed an upward trend commencing at 2 min post-SAB, whereas SpO_2 remained almost stable (Fig. 4: lower). In the Th and Ce groups, significance was tested between the PI values in the upper and lower limbs as these values in both groups showed an upward trend at post-SAB (Fig. 5). No significant difference was observed in the PI values in the finger between the Th and Ce groups (Fig. 5: upper). On the other hand, a comparison of the PI values in the toe revealed that it was higher in the Th group than in the Ce group at 2 min post-SAB (Fig. 5: lower). The anesthesia level and the presence of clinical symptoms and use of vasopressors in each group are shown in Table 4. In the Ce group, the average level of anesthesia reached the upper thoracic (Th2) and the highest average level the cervical (C5/6) soon after application of SAB. Vasopressors were administered in 3 patients, and clinical symptoms (numbness of both hands) were observed in 3 patients.

DISCUSSION

Block of the sympathetic nerve by SAB causes the vessels of the lower limbs to expand and blood flow to increase, which results in contraction of the blood vessels in the upper limbs together with a reduction in blood flow [4].

In the present study, elevation in the PI value in the toe in the Con group post-SAB indicates an improvement in blood flow. On the other hand, the PI value in the finger showed little change. In the Con group, the highest level of SAB was Th6, which is the optimal level of anesthesia. This can explain why the vital signs were stable (Fig. 2: middle-low). The 5th thoracic sympathetic nerve level.(Th5) is required when performing SAB for CS. The subarachnoid space in pregnant women is compressed and narrowed by the expanded uterus. Injecting a local anesthetic into the narrow subarachnoid space means that the anesthetic is more likely to spread, increasing the level of anesthesia. This may explain why the anesthesia level reaches the cervical spine level in some cases. We previously noticed that when SAB reached the cervical spine level during CS, the PI value in the finger showed elevation, which is what prompted us to undertake the present study. It is important to avoid respiratory depression when spinal anesthesia has reached the cervical spine level. This respiratory depression is caused by block of the phrenic nerve (C4). It is very important to recognize the risk of respiratory depression early on. Here, when SAB reached the cervical spine level, the PI value in the finger showed elevation.

This was because when the sympathetic nerve is blocked and the vessels of the upper limbs are extended, blood flow is increased. This mechanism may be the same as that observed with stellate ganglion block. The stellate ganglion is formed by fusion of the 1st thoracic sympathetic ganglion and the inferior cervical ganglion. Stellate ganglion block acts on the sympathetic nervous system, causing an improvement in blood flow in the upper limbs and elevation of the PI value in the finger [5].

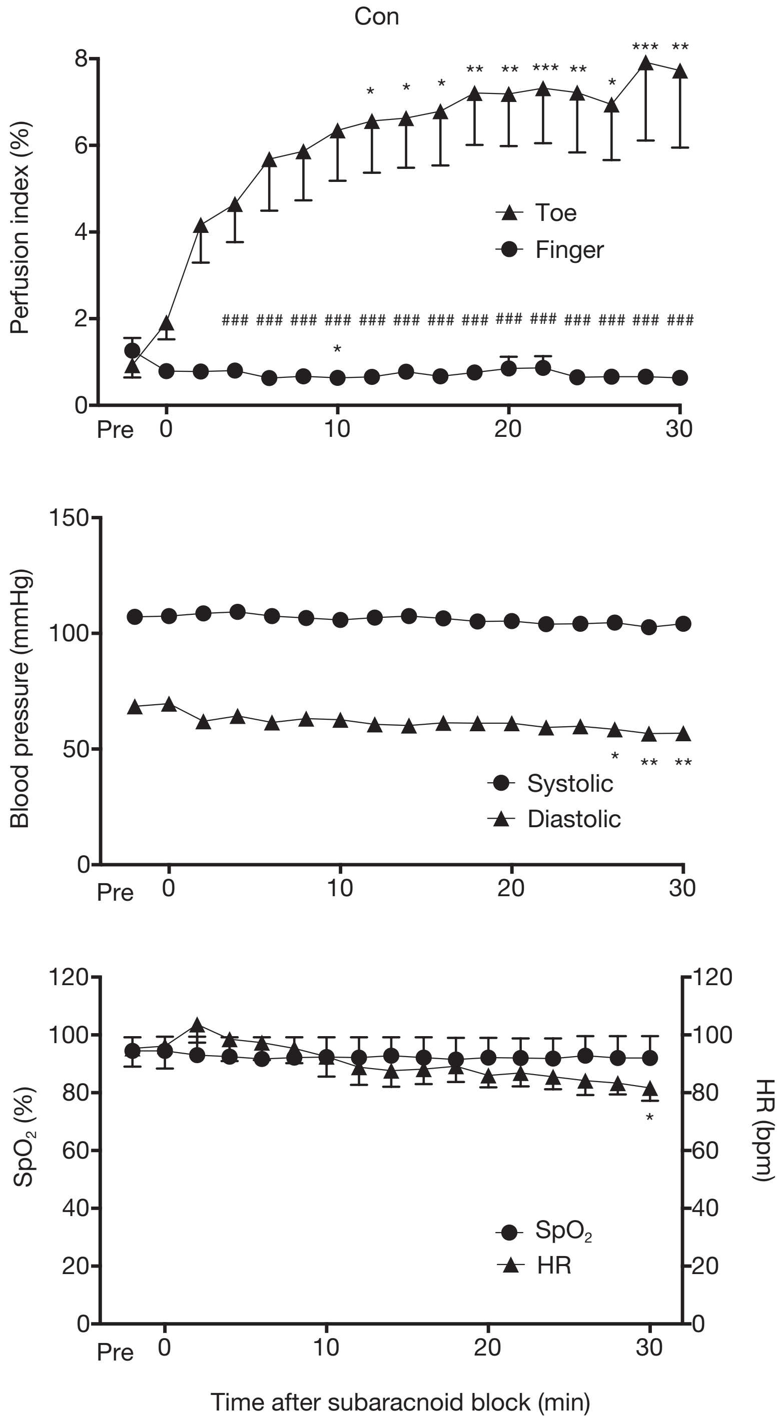

Fig. 2 PI value in the finger and toe at pre- and post-SAB in the Con group (upper), Blood pressure at pre- and post-SAB in the Con group (middle) and Heart rate and SpO_2 at pre- and post-SAB in the Con group (low).
Where asterisks have been placed above each value for perfusion index, blood pressure or SpO_2, this indicates significant differences in comparison with for Pre-SAB according to Dunn's post-hoc test following the Kruskal-Wallis test; $^{*}P < 0.05$, $^{**}P < 0.01$ and $^{***}P < 0.001$. Where sharp symbols have been placed above each value for finger, this indicates significant differences in comparison with toe according to Dunn's post-hoc test following two-way repeated measures ANOVA; ###$P < 0.001$.

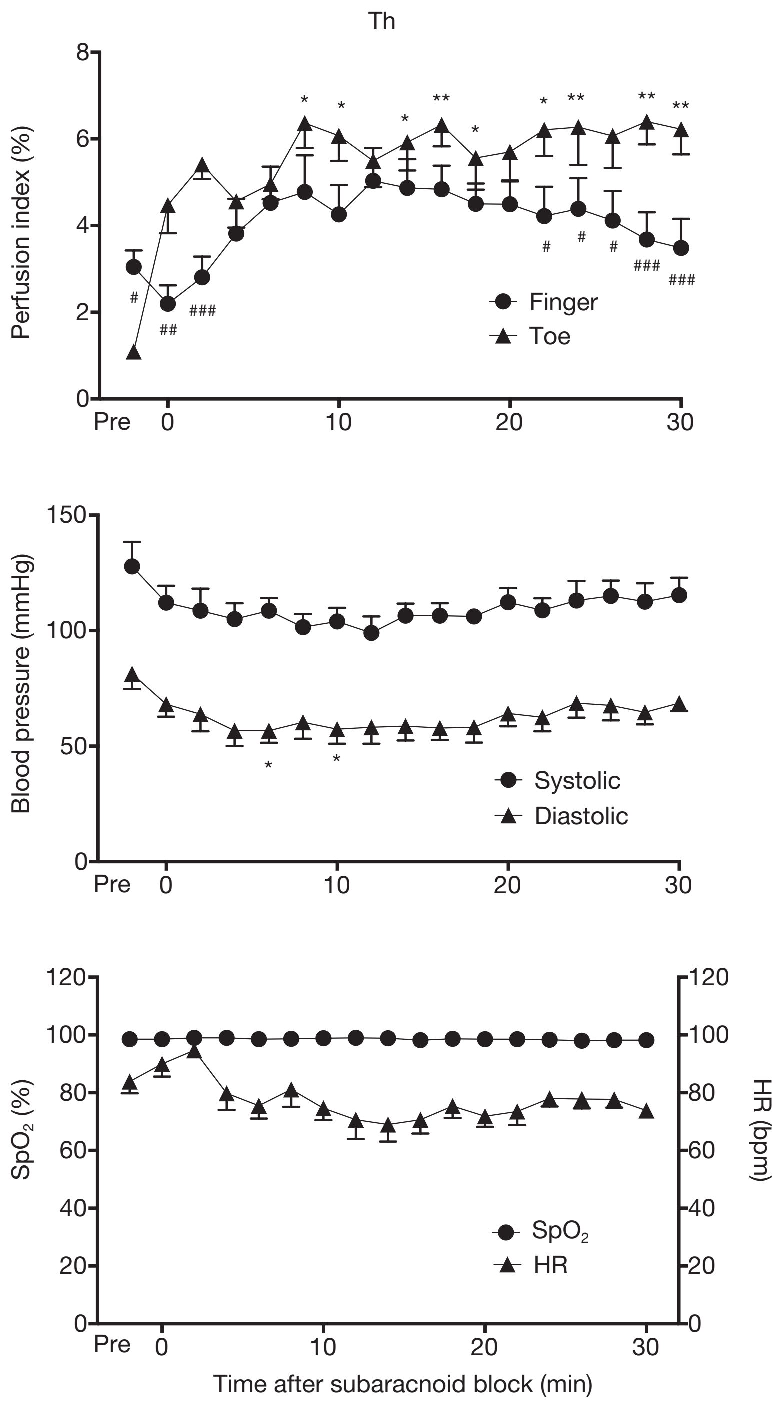

Fig. 3 PI value in the finger and toe at pre- and post-SAB in the Th group (upper), Blood pressure at pre- and post-SAB in the Th group (middle) and Heart rate and SpO_2 at pre- and post-SAB in the Th group (low).
Where asterisks have been placed above each value for perfusion index, blood pressure or SpO_2, this indicates significant differences in comparison with for Pre-SAB according to Dunn's post-hoc test following the Kruskal-Wallis test; *$P < 0.05$ and **$P < 0.01$. Where sharp symbols have been placed above each value for finger, this indicates significant differences in comparison with toe according to Dunn's post-hoc test following two-way repeated measures ANOVA; #$P < 0.05$, ##$P < 0.01$ and ###$P < 0.001$.

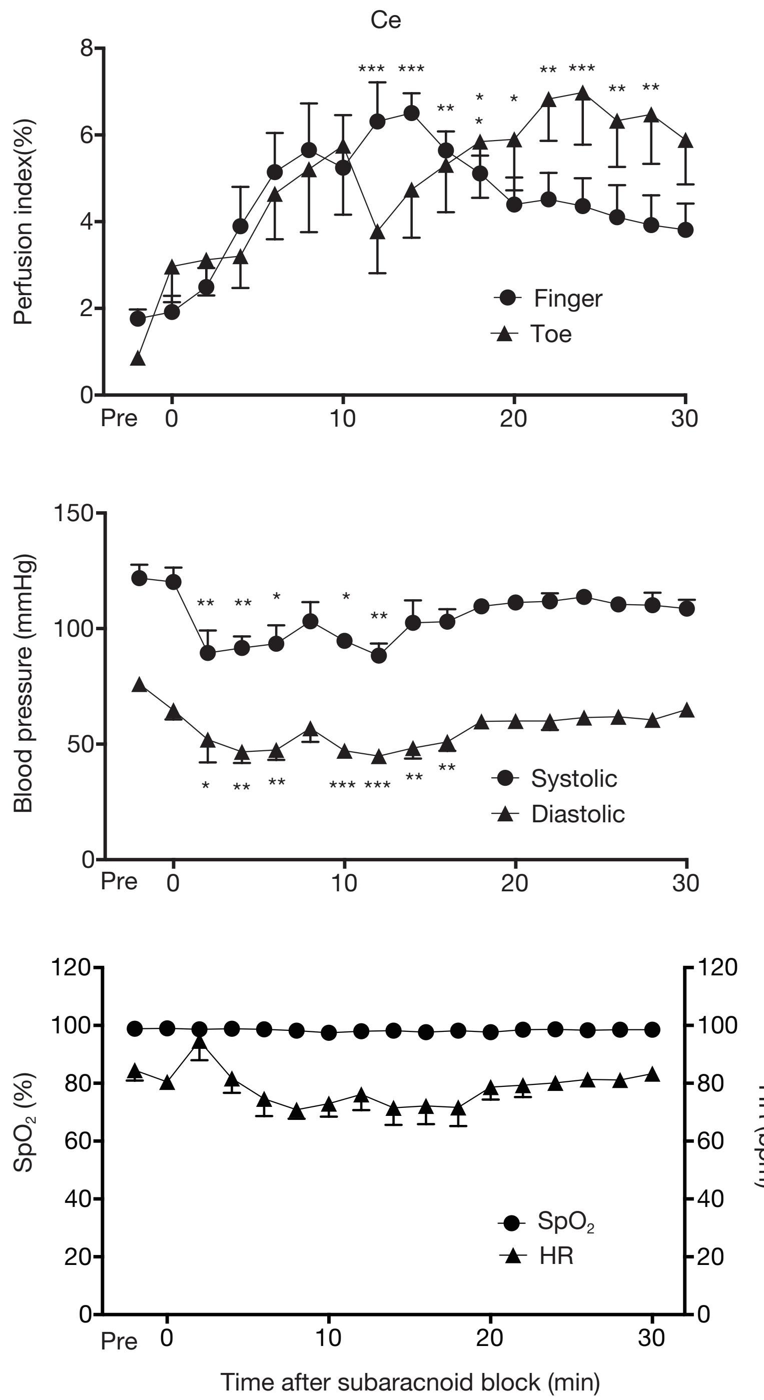

Fig. 4 PI value in the finger and toe at pre- and post-SAB in the Ce group (upper), Blood pressure at pre- and post-SAB in the Ce group (middle) and Heart rate and SpO_2 at pre- and post-SAB in the Ce group (low).
Where asterisks have been placed above each value for perfusion index, blood pressure or SpO_2, this indicates significant differences in comparison with for Pre-SAB according to Dunn's post-hoc test following the Kruskal-Wallis test; *P < 0.05, **P < 0.01 and ***P < 0.001.

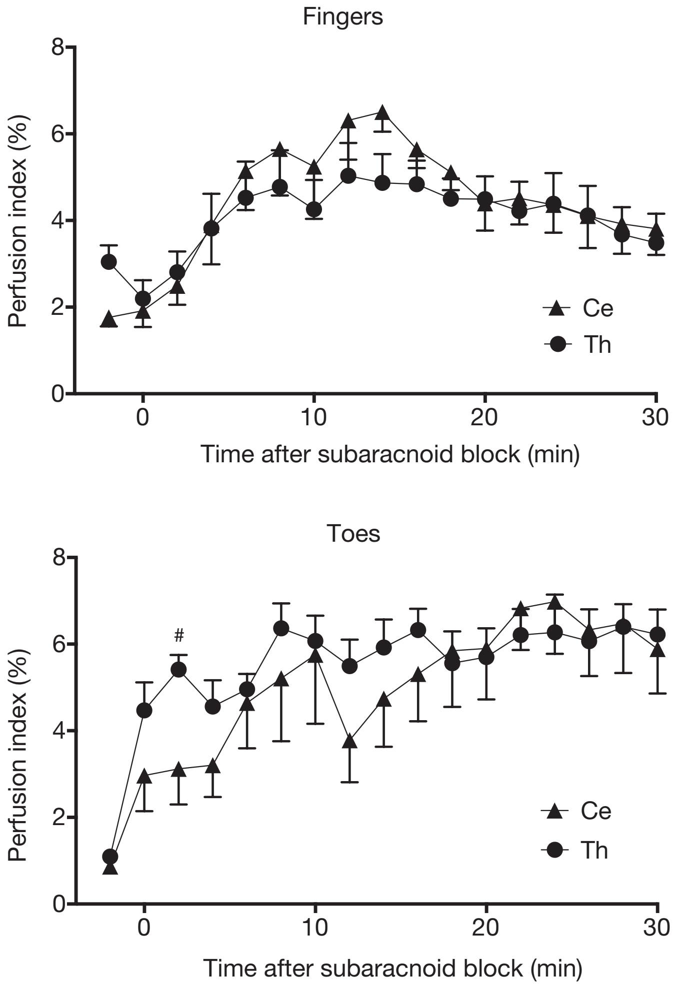

Fig. 5 PI value in the fingers at pre- and post-SAB in the Ce group and Th group (upper) and PI value in the toes at pre- and post-SAB in the Ce group and Th group (low). Where sharp symbol has been placed above each value for Ce, this indicates significant differences in comparison with Th according to Dunn's post-hoc test following two-way repeated measures ANOVA; #P < 0.05.

Table 4 Average anesthesia level post-SAB and use of vasopressors and clinical symptoms in the Con, Th and Ce groups

	Average anesthesia level after 2 min SAB	Highest average anesthesia level at 8–10 min post-SAB	Use of vasopressors	Clinical symptoms
Con group	Th9	Th6	0	0
Th group	Th8	Th3	0	0
Ce group	Th2	C5/6	3	3 *

* : number of patients who had numbress of both hands at 10 min post-SAB

In the present study, it was found that the PI value in the finger was elevated when anesthesia reached the cervical spine (Ce group) (Fig. 4: upper) and thoracic spine (Th group) level (Fig. 3: upper). In the Th group, PI showed an immediate, but temporary decrease post-SAB (Fig. 3: upper). One study reported a decrease in PI when the sympathetic nervous system was activated by pain stimulus [6].

At immediately post-SAB, heart rate showed an upward trend, in spite of no ephedrine being used (Fig. 3: low), suggesting involvement of the sympathetic nervous system. Blood circulation in the upper limb showed an improvement when the thoracic sympathetic nerves (Th2-4) were blocked [7]. This may explain why the PI value in the finger was elevated at post-SAB in both the Ce and Th groups. In other words, stellate ganglion and thoracic sympathetic blockade have a similar effect on the upper limbs [8]. No significant difference was observed in the PI values in the finger between the Ce and Th groups (Fig. 5: upper). This likely reflects the fact that vasopressors (ephedrine) were used in 3 cases out of 6 in the Ce group.

Traditionally, ephedrine has been the first choice as it barely affects uterine blood flow during CS. However, recently, phenylephrine has also been recommended, as it allows the pH in the umbilical artery to be maintained at a constant more easily than ephedrine [9]. Phenylephrine acts selectively and strongly on α receptors. In this study, we avoided the use of phenylephrine as we believed that this strong stimulation of α receptors would deflate the peripheral vasculature and thus affect the PI value. Ephedrine, on the other hand, acts on α and β receptors. Ephedrine-induced stimulation of α receptors is not as strong as that induced by phenylephrine.

However, the possibility that ephedrine-induced stimulation of α receptors affected the PI values in the upper limb here cannot be ruled out. The frequency of hypotension after spinal anesthesia is 80% or more[10]. Post-SAB hypotension is a drawback of this anesthetic procedure. In this study, ephedrine was administered at 80 mmHg or less. This was done for the following reasons: 1) it is possible that prolongation of hypotension causes fetal bradycardia and acidosis due to low uterine blood flow, affecting the prognosis of the fetus; and 2) empirically, the incidence of nausea and vomiting increases when systolic blood pressure falls to 80 mmHg or lower. The mechanism underlying this nausea and vomiting remains to be elucidated, but cerebral hypoxemia and a reduction in cerebral blood flow by decreased blood pressure may be a factor [10]. The present results indicate that no nausea or vomiting was observed as blood pressure was more or less maintained. A significant difference was observed in the PI value in the toe after 2 min post-SAB between the Ce and Th groups (Fig. 5: lower). In the Th group, the PI value in the toe showed elevation, soaring at 2 min post-SAB. In the Ce group, on the other hand, the PI value in the toe showed a gradual elevation post-SAB. This difference in the elevation in the PI value among both groups may have been due to changes in blood pressure post-SAB. Change in blood pressure post-SAB was gradual in the Th group (Fig. 3: middle).

In the Ce group, however, blood pressure showed a significant decrease from immediately after application of SAB (Fig. 4: middle). The reduction in blood pressure observed in the Ce group may have been due to the SAB level reaching the upper thoracic spine (Th2) at 2 min post-SAB, resulting in extensive block of the sympathetic nerve (Table 4). This decrease in blood pressure was why there was only a small increase in blood flow and a gradual increase in the PI values in the toe.

In the Ce group, heart rate showed an increase consistent with decrease in blood pressure (Fig. 4: lower). This temporary increase in heart rate may have been due to ephedrine-induced stimulation of β receptors. In the Ce group, three patients complained of numbness of both hands at 10 min post-SAB, indicating that SAB had reached the cervical spine level. Numbness of both hands (clinical symptoms) continued for more than 10 min post-SAB. It is difficult to say whether the appearance of clinical symptoms is useful in the early detection of high SAB.

The present data do not support our hypothesis that a rise in the finger PI value is useful in early detection of block at the cervical spine level (high SAB).

However, the small sample size (n = 6), which is one of the limitations of this study, may have masked the potential PI value rise. In addition, measurements of blood pressure immediately after SAB and the toe PI value, along with recognition of hand numbness, may be useful in early detection of high SAB. Further studies are warranted to explore such possibilities.

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