Preoperative perfusion index

by Mukri P Nasution

Submission date: 20-Sep-2023 10:13PM (UTC+0800)
Submission ID: 2171600939
File name: Preoperative_perfusion_index.pdf (380.76K)
Word count: 4687
Character count: 26615

Original Article

JOURNAL OF PERIOPERATIVE PRACTICE

AfPP PROGRESSING SAFER SURGERY The Association for Perioperative Practice

Journal of Perioperative Practice
0(0) 1–7

DOI: 10.1177/1750458920979263
journals.sagepub.com/home/ppj
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Preoperative perfusion index as a predictor of post-anaesthetic shivering in caesarean section with spinal anaesthesia

Mukri P Nasution, Mariza Fitriati, Anna S Veterini, Prihatma Kriswidyatomo and Arie Utariani

Abstract

Background: Post-anaesthetic shivering is frequently preceded by a decrease in peripheral blood flow. Perfusion index is a fast non-invasive method to assess peripheral blood flow, thus might be correlated with post-anaesthetic shivering.

Aim: To analyse the relationship between preoperative perfusion index and post-anaesthetic shivering in patients undergoing caesarean section with spinal anaesthesia.

Methods: In this prospective observational study, preoperative perfusion index measurements were performed on 40 participants who were undergoing elective caesarean section under spinal anaesthesia. Spinal anaesthesia was performed using Lidodex (Lignocaine + Dextrose 5%) at vertebrae L4–L5 or L3–L4 interspace. Shivering was observed until 120 minutes according to the Crossley and Mahajan scale. Statistical analysis was performed to examine the correlation and cut-off of preoperative perfusion index as a predictor for post-anaesthetic shivering.

Result: There was a significant relationship between preoperative perfusion index with the incidence ($p = 0.005$) and the degree ($p = 0.014$) of post-anaesthetic shivering. The preoperative perfusion index cut-off value based on the ROC curve was 4.2 (AUC = 0.762, $p = 0.002$) with a sensitivity of 73.9% and specificity of 88.2%. Participants with preoperative PI < 4.2 had a greater risk of post-anaesthetic shivering ($p < 0.001$, RR = 3.13).

Conclusion: Preoperative perfusion index less than 4.2 can predict post-anaesthetic shivering in patients undergoing caesarean section with spinal anaesthesia.

Keywords

Perfusion index / Spinal anaesthesia / Caesarean section / Post-anaesthetic shivering

Provenance and Peer review: Unsolicited contribution; Peer reviewed; Accepted for publication 14 November 2020.

Introduction

Shivering is defined as an involuntary, oscillatory muscular activity to increase core temperature (Buggy & Crossley 2000, Charuluxananan et al 2009, Witte & Sessler 2002). Post-anaesthetic shivering is a common and challenging complication of anaesthesia which may occur during and after regional or general anaesthesia (Bhattacharya et al 2003, Charuluxananan et al 2009, Witte & Sessler 2002). The incidence of post-anaesthetic shivering in patients under general anaesthesia is around 40–60%, whereas under regional anaesthesia is up to 60% (Cobb et al 2016, Lopez 2018). In shivering, oxygen consumption, carbon dioxide production and metabolic rate might increase (Charuluxananan et al 2009, Lopez 2018, Witte & Sessler 2002). Shivering might also impair monitoring, increase intraocular and intracranial pressures, place strain on the surgical wound and can be worrying to the patient during labour and delivery (Lopez 2018).

Pathogenesis of post-anaesthetic shivering differs in general and regional anaesthesia. General anaesthesia might impair the central thermoregulation, while spinal anaesthesia affects central and peripheral thermoregulation. Spinal anaesthesia enlarges the inter-threshold range by raising the sweating threshold and

Department of Anesthesiology and Intensive Care, Faculty of Medicine Airlangga University, Dr. Soetomo General Academic Hospital Surabaya, East Java, Indonesia

Corresponding author:
Arie Utariani, Department of Anesthesiology and Intensive Care, Faculty of Medicine – Dr Soetomo General Academic Hospital, Airlangga University Surabaya, Mayjend Prof. Dr. Moestopo Street No 6-8, Airlangga, Gubeng, Surabaya, East Java 60285, Indonesia.
Email: arie.utariani@fk.unair.ac.id

decreasing the vasoconstriction and shivering thresholds (Lopez 2018, Witte & Sessler 2002). Thus, more heat will be lost, and more shivering incidences will occur in neuraxial anaesthesia (Lopez 2018). In caesarean delivery under spinal anaesthesia, the primary cause of perioperative hypothermia is due to intravascular fluid redistribution from the core to peripheral compartment below the level of the block, thus predisposing the body to radiant heat loss (Lopez 2018, Witte & Sessler 2002). Spinal anaesthesia also slightly decreases the threshold for triggering vasoconstriction above the level of the block (Lopez 2018).

Management of post-anaesthetic shivering is crucial to reduce oxygen consumption and maintain haemodynamic stability (Bhattacharya et al 2003, Lopez 2018). Previous studies by Lopez (2018), Chung et al (2012) and Horn et al (2002) found that perioperative active cutaneous warming effectively prevents post-anaesthetic shivering in caesarean section patients. The current American Society of Anesthesiologists Task Force on Postanaesthetic Care guidelines also recommend forced-air warming, a common method of active cutaneous warming, to reduce shivering in the perioperative setting (Apfelbaum et al 2013). However, at present, there is still no method which can predict the occurrence of post-anaesthetic shivering. The usage of a diagnostic tool, such as perfusion index, to predict the occurrence of shivering could help in making a better preoperative preparation and reducing the incidence of post-anaesthetic shivering.

Perfusion index (PI) is a non-invasive measurement of peripheral perfusion using a pulse oximeter (Dugappa et al 2017, Lima & Bakker 2005). PI is the ratio between the pulsatile signal (arterial blood) with non-pulsatile signal (skin, other tissues and non-pulsatile blood) derived from the amount of infrared light absorbed (Lima & Bakker 2005, Toyama et al 2013). Various studies carried out previously have shown that PI can be used to assess haemodynamic parameters, predict hypotension after anaesthesia and monitor peripheral perfusion dynamics due to changes in peripheral vascular tone (Dugappa et al 2017, Lima et al 2002, Toyama et al 2013). Another previous study shown PI correlates with post-anaesthetic shivering in patients with lower abdominal surgery under general anaesthesia (Kuroki et al 2014). However, research on PI as a predictor of post-anaesthetic shivering is still limited.

Therefore, this study aimed to examine whether preoperative PI correlates with incidence and degree of post-anaesthetic shivering, and whether preoperative PI could be a predictor for post-anaesthetic shivering. We hypothesised that preoperative PI could predict post-anaesthetic shivering in patients undergoing caesarean section under spinal anaesthesia, since PI and shivering were both correlated with peripheral vascular tone.

Material and methods

Study design and setting

This prospective observational study was approved by the Institutional Ethics Committee (Airlangga University Hospital, Indonesia) with approval number 191/KEH/2019. Informed written consent was obtained from every participant in the study. A total of 40 gravida participants undergoing caesarean section under spinal anaesthesia who met the inclusion criteria were invited to take a part.

In this study, we hypothesised that the relationship between peripheral perfusion and post-anaesthetic shivering during caesarean delivery under spinal anaesthesia could be assessed by using PI values derived from a pulse oximeter. To address our hypothesis, we examined whether preoperative PI value correlates with the incidence and degree of post-anaesthetic shivering in caesarean delivery under spinal anaesthesia and whether preoperative PI value could predict patient at risk for post-anaesthetic shivering.

Participant selection criteria

The inclusion criteria of this study were as follows: (1) patients undergoing caesarean section under spinal anaesthesia, (2) age 18–40 years, (3) PS-ASA I-II, (4) consented to participate in the study.

Exclusion criteria in this study were: (1) patients who given drugs that could affect thermoregulation, (2) preoperative temperature >38°C or <36°C, (3) Body mass index (BMI) >40kg/m2.

Participants consented to take part in the study would be withdrawn due to: (1) a complication during surgery, such as systemic allergy, anaphylactic reaction or cardiac arrest (2) bleeding with blood loss >20% estimated blood volume (EBV), (3) duration of operation <20 minutes or >120 minutes, (4) spinal block height more than Thoracal-4 or less than Thoracal-6, (5) failure of spinal anaesthesia, (6) surgery requiring conversion to general anaesthesia.

Data collection

In each participant, electrocardiogram, radial arterial blood pressure and arterial oxygen saturation monitoring every 5 minutes after arrival in the operating theatre. Preoperative blood pressure, heart rate and temperature (tympanic) were measured. Perfusion index was measured at a forefinger contralateral to the side in which intravenous catheters had been placed to avoid the possible influence of infusions or transfusions on local temperature. In each participant, the ambient operating room temperature was maintained at 19–22°C before and during the operation. Participants were covered with one ply of cotton blanket preoperatively. All

fluid was kept at room temperature (20–23°C) before infusion. All participants were given ringer lactate loading dose of 10mL/kg in 10 minutes. Spinal anaesthesia was performed using Lidodex (Lignocaine + Dextrose 60–75mg) at vertebrae L4–L5 or L3–L4 interspace.

Post-anaesthetic shivering was observed for 120 minutes after the first incision. Post-anaesthetic shivering was assessed according to the Crossley and Mahajan scale of shivering grade (0, no shivering; 1, piloerection or peripheral vasoconstriction but no visible muscle activity; 2, muscular activity in only one muscle group; 3, muscular activity in more than one muscle group but not generalised shaking; 4, shivering involving the whole body) (Crossley & Mahajan 1994). Shivering grades 0 and 1 were classified as non-shivering; shivering grades 2–4 were considered as shivering.

In participants who developed hypotension (decrease of SBP >20%), a dose of 5mg of IV ephedrine was administered. In participants who developed post-anaesthetic shivering ≥grade a 2.25mg dose of IV pethidine was administered, which could be repeated every 15–20 minutes, if required. Participants with nausea or vomiting were given intravenous ondansetron (4mg).

Statistical analysis

Statistical analysis was performed using SPSS statistic software version 25. Data are presented as mean ± SD or median (range). The unpaired two-tailed *t* test or Mann–Whitney test was used when appropriate to evaluate the influence of participants' demographic, obstetric and preoperative clinical characteristics. Perfusion index results between participants with and without post-anaesthetic shivering was compared using Mann–Whitney test. Perfusion index results in participants with different shivering grade were compared using Kruskal–Wallis test. Correlation between perfusion index from with incidence and grade of post-anaesthetic shivering then assessed using Pearson correlative or Spearman rank test. Receiver operating characteristic (ROC) curve analysis was used to evaluate whether perfusion index could predict the incidence of post-anaesthetic shivering and cut-off for it; results are reported with 95% confidence interval (CI).

Results

Of the total 40 participants who participated in this study, 23 participants (57.5%) exhibited post-anaesthetic shivering (grades 2–4). All participants exhibiting post-anaesthetic shivering received a 50mg dose of intravenous pethidine. Fourteen participants (63.6%) who exhibited post-anaesthetic shivering received intravenous ephedrine due to occurrence of hypotension.

Table 1 shows participants' demographic, obstetric and preoperative clinical characteristics. There was no difference in age, weight, height and body mass index (BMI) between participants with and without shivering ($p = 0.841$; $p = 0.239$; $p = 0.201$; $p = 0.411$). There was also no difference in parity, gravidity and gestational age ($p = 0.721$; $p = 0{,}955$; $p = 0.841$). There was no difference in preoperative systolic blood pressure, heart rate and body temperature between participants

Table 1 Participants' demographic, obstetric and preoperative clinical characteristics

	Shivering group ($n = 23$)	Non-shivering group ($n = 17$)	*p*-value
Demographic			
Age (years)	31.09 ± 7.13	31.53 ± 6.59	0.841*
Weight (kg)	69.22 ± 12.50	74.41 ± 14.25	0.239*
Height (cm)	152 (144–165)	155 (143–165)	0.201**
Body mass index	30.3 (22.5–39.0)	33.0 (20.0–38.6)	0.411**
Obstetric			
Parity	2 (0–3)	1 (0–3)	0.721**
Gravidity	3 (1–5)	3 (1–5)	0.955**
Gestational age (weeks)	38 (36–40)	38 (36–41)	0.841**
Preoperative clinical characteristics			
Systolic blood pressure (mmHg)	129.56 ± 14.68	125.18 ± 7.22	0.264**
Diastolic blood pressure (mmHg)	81.26 ± 9.05	72.29 ± 9.52	0.005**
Mean arterial pressure (mmHg)	97.74 ± 9.48	90.47 ± 7.15	0.009**
Heart rate (beats/min)	86.69 ± 12.74	84.35 ± 11.09	0.539**
Body temperature	36.6 (36.4–37.2)	36.6 (36.4–37.0)	0.672**
PS-ASA (I/II) (*n*)	0/23	0/17	–
PI	2.8 (0.1–11.0)	5.2 (3.9–7.4)	0.005**
Shivering grade (0/1/2/3/4) (*n*)	0/0/4/16/3	17/0/0/0/0	–

Note: Date are expressed as mean ± standard deviation or median (range).
*Unpaired two tailed-*t* test.
**Mann–Whitney test.

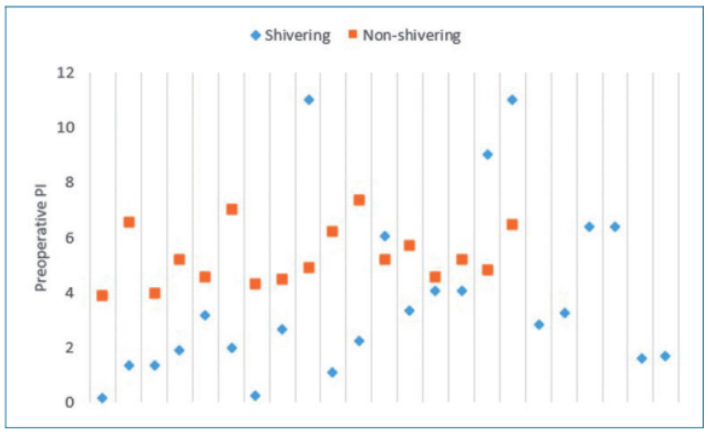

Figure 1 Preoperative perfusion index in non-shivering and shivering participants was compared. Statistically significant differences between participants with and without post-anaesthetic shivering at each point were indicated as $p = 0.005$. Correlations between perfusion index and shivering incidence ($R = -0.449$, $p = 0.004$, $n = 40$) were evaluated.

Table 2 Preoperative PI value in different shivering grades

Shivering grade	Preoperative PI	*p* value
0 ($n = 17$)	5.2 (3.9–7.4)	0.014*
1 ($n = 0$)	–	
2 ($n = 4$)	5.1 (3.4–6.4)	
3 ($n = 16$)	2.45 (0.1–11.0)	
4 ($n = 3$)	2.0 (1.9–11.0)	

*Kruskal–Wallis test.
Note: Date are expressed as median (range).

between both groups ($p = 0.264$; $p = 0.539$; $p = 0.672$). However, preoperative diastolic blood pressure and mean arterial pressure were significantly different ($p = 0.005$; $p = 0.009$). Preoperative diastolic blood pressure and mean arterial pressure were higher in participants with post-anaesthetic shivering.

Median preoperative PI value was significantly lower in participants elicited post-anaesthetic shivering compared with participants without shivering (shivering 2.8, non-shivering 5.2; $p = 0.005$) (Table 1, Figure 1). There was also significant difference of median preoperative PI value in different shivering grades ($p = 0.014$) (Table 2, Figure 2). In addition, perfusion index significantly correlated with incidence ($p = 0.004$) (Figure 1) and degree of post-anaesthetic shivering ($p = 0.003$) (Figure 2).

The ROC analysis revealed that preoperative PI was suitable to detect patient at risk for post-anaesthetic shivering (AUC = 0.762, $p = 0.005$) (Figure 3). The baseline PI cut-off point that predicted post-anaesthetic shivering as determined by the ROC analyses was 4.2 with a sensitivity of 73.9% (95% CI), a specificity of 88.2% (95% CI), a positive predictive value of 89.5% and a negative predictive value of 71.4% ($p < 0.001$).

The incidence and degree of post-anaesthetic shivering analysed according to the baseline PI cut-off point of 4.2 determined by the above ROC analysis. Nineteen participants (47.5%) had low baseline PI ($PI < 4.2$) and post-anaesthetic shivering was observed in 17 of those participants (89.5%), whereas 21 participants (52.5%) had high baseline PI ($PI \geq 4.2$) and post-anaesthetic shivering was observed in six of those participants (28.6%). The incidence of post-anaesthetic shivering in Group I ($PI < 4.2$) was higher than Group II ($PI \geq 4.2$). This was statistically highly significant ($p < 0.001$, risk ratio = 3.13). In Group I, two participants had grade 0 shivering, two participants had grade 2 shivering, 13 participants had grade 3 shivering and two participants had grade 4 shivering. In Group II, 15 participants had grade 0 shivering, two participants had grade 2 shivering, three participants had grade 3 shivering, and one participant had grade 4 shivering (Table 3). This was also statistically significant ($p < 0.001$).

Discussion

Shivering occurs mainly as a response to central hypothermia. This response involves thermoregulatory vasoconstriction to reduce skin heat loss and maintain the core's heat. Maximal vasoconstriction usually occurs before thermoregulatory shivering. When the core temperature decreases to a certain point, known as the shivering threshold, thermoregulatory shivering will occur (Buggy & Crossley 2000, Crowley & Buggy 2008). Kumar and Nadkarni (2017) have described that changes in perfusion index value may occur as a result of local vasoconstriction (decreased perfusion index) or vasodilation (increased perfusion index) in the skin at the monitoring site.

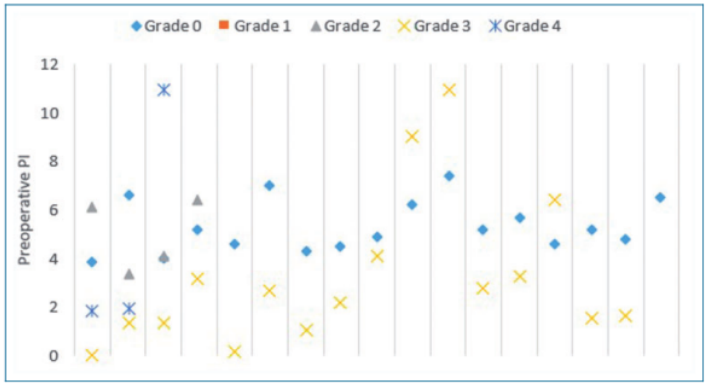

Figure 2 Preoperative perfusion index in different shivering grades was compared. Statistically significant differences between participants with different shivering grades were indicated as $p = 0.014$. Correlations between perfusion index and shivering incidence ($R = -0.464$, $p = 0.003$, $n = 40$) were evaluated.

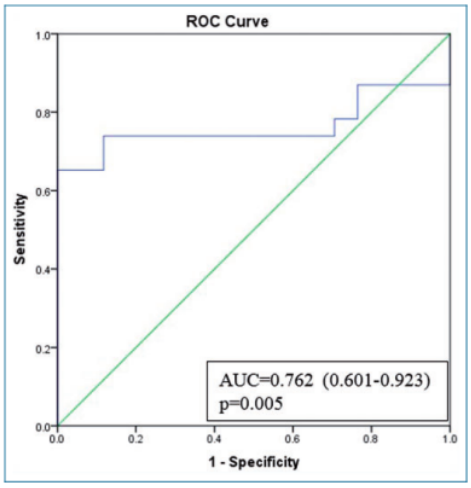

Figure 3 ROC curves for the preoperative PI in caesarean delivery under spinal anaesthesia. The optimal cut-off value for predicting the incidence of shivering in PI was 4.2. AUC: area under the ROC curve, with 95% CIs given in parentheses.

Post-anaesthetic shivering is a common yet challenging complication after spinal anaesthesia in caesarean delivery as it causes discomfort, such as a cold sensation, in patients during labour and delivery (Witte & Sessler 2002). In one previous study conducted by Irawan (2018), 16.7% caesarean section patients having had a spinal anaesthesia experienced post-anaesthetic shivering. In another study by Kuroki et al (2014), 35.7% caesarean section patients experienced post-anaesthetic shivering after spinal anaesthesia. Two studies (Luggya et al 2016, Susilowati et al 2017) identified intraoperative hypothermia and hypotension as the main associated causes of post-anaesthetic shivering. However, they also stated that lower preoperative peripheral vascular tone may have increased the incidence of shivering which was matched by our findings.

Peripheral vascular tone can be measured by plethysmography; however, it is invasive and not readily available for clinical management in the elective settings. Non-invasive plethysmographic pulse wave monitoring is found in pulse oximeters and is available for daily use (Babchenko et al 2001). A previous study by Ginosar et al (2009) had demonstrated that an increase in PI was a sensitive indicator of the development of epidural-induced sympathectomy. Other studies also showed that a decrease in PI could be a predictor to identify intravascular injection of epinephrine-containing epidural test dose and inadequate perfusion in critically ill patients (Lima et al 2002, Mowafi et al 2009).

Kuroki et al (2014) reported that perfusion index reflects peripheral perfusion and changes in core-to-peripheral temperature differences. When perfusion index changes with peripheral blood flow, perfusion index can reflect the peripheral temperature gradient and hence the thermoregulatory response, such as peripheral vasoconstriction which precedes shivering. Another study by House and Tipton (2002) using laser Doppler flowmetry revealed a linear relationship between peripheral blood flow and temperature gradients at the fingertips. Previous studies by Lima et al (2002) and Kuroki et al (2014) have described that perfusion index also correlates with skin temperature and core-to-peripheral temperature gradients. Perfusion index can reflect changes in peripheral temperature due to thermoregulatory vasoconstriction. Significantly lower pre-anaesthetic perfusion index has been recorded in patients with post-anaesthetic shivering (Kuroki et al 2014).

This study showed that there was no significant difference in age, body weight, body height and BMI

Table 3 Shivering grades within group I (PI <4.2) and group II (PI ≥4.2)

		Shivering grade				
		0	2	3	4	*p* value
Preoperative PI	<4.2	2 (10.5%)	2 (10.5%)	13 (68.4%)	2 (10.5%)	0.001*
	≥4.2	15 (71.4%)	2 (9.5%)	3 (14.3%)	1 (4.8%)	

*Chi-square test.

between participants that shivered and those that did not. Whilst a study by Susilowati et al (2017) stated that there was a significant correlation between older age and lower BMI with hypothermia and shivering, the findings from this study correlate to the results of a previous study by Kuroki et al (2014) that showed no significant difference in age and BMI in patients with and without shivering.

In this study, there was no significant difference in parity, gravidity and gestational age between the shivering and non-shivering group. There was also no significant difference in systolic blood pressure and heart rate, but diastolic blood pressure and mean arterial pressure were significantly higher in the shivering group. Kuroki et al's study (2014) showed that there was no significant difference in mean arterial pressure and heart rate in both groups. Preoperative temperature in shivering and non-shivering participants did not differ significantly in this study; however, a previous study by Luggya et al (2016) in caesarean section patients revealed that hypotension and hypothermia could be a risk factor for shivering.

We found a significant difference in preoperative IP values in patients who experienced shivering and those who did not. Participants who shivered had a lower median preoperative IP value than non-shivering patients. The findings also suggest that perfusion index was significantly correlated with the degree of shivering. The lower the median value of preoperative IP, the higher the degree of shivering after spinal anaesthesia. This result correlates to the findings of the study conducted by Kuroki et al (2014) which stated that core-to-peripheral temperature correlated with changes in perfusion index, and perfusion index values were significantly different in patients with shivering and non-shivering, with a lower PI in the shivering group.

ROC curve performed in this study obtained an optimal cut-off value of the preoperative perfusion index as a predictor for post-anaesthetic shivering in caesarean section under spinal anaesthesia by 4.2 with a sensitivity of 73.9% and specificity of 88.2%. The incidence of shivering in patients with preoperative PI <4.2 was higher than those with PI ≥4.2. Most patients with preoperative PI <4.2 experienced grade 3 shivering, while most patients with PI ≥4.2 had grade 0 shivering or did not experience shivering. Patients with preoperative PI values PI<4.2 had a risk of developing post-anaesthetic shivering 3.13 times greater than patients with PI ≥4.2.

There was a significant correlation between the preoperative perfusion index (cut-off value ≥4.2) and the incidence of shivering after spinal anaesthesia. Nevertheless, there are still no previous studies that have analysed perfusion index with a cut-off value of 4.2 with the incidence of shivering after spinal anaesthesia in caesarean section patients. Kuroki et al (2014) obtained a cut-off value of <1.30 to differentiate between patients with and without post-anaesthetic shivering, with a sensitivity of 78% (95% CI 40–97%) and specificity of 93% (95% CI 68–100%). However, our study found that there was no significant difference in the incidence of post-anaesthetic shivering in patients with PI <1.3 and ≥1.3. The difference in cut-off values obtained in this study with the previous study might be caused by a difference in types of surgery and anaesthesia. Higher preoperative PI cut-off value in our study may also have reflected lower peripheral vascular tone secondary to pregnancy.

Kuroki et al's (2014) study was conducted not only in obstetric patients but all patients who underwent gastrointestinal or gynaecologic laparotomy under general anaesthesia. Whereas in our study, all of the respondents were obstetric patients with caesarean section under spinal anaesthesia. According to Dugappa et al (2017), there is decreased systemic vascular resistance and increased total blood volume and cardiac output in pregnancy. The reduction of systemic vascular resistance may vary in pregnant women, depending on various factors. This decrease in vascular tone will correspond to a higher perfusion index value due to an increase in the pulsatile component due to vasodilation.

Shivering is uncomfortable for the patients, and some of them even found the accompanying cold sensation was worse than the pain caused by the surgery (Witte & Sessler 2002). Predicting post-anaesthetic shivering is important to ensure early identification and management of the risk in caesarean section patients. Interventions that can be done to reduce the incidence of post-anaesthetic shivering in caesarean section patients are intravenous fluid heating devices, increased ambient theatre temperatures, heating lamps and heating blankets, and pharmacological interventions.

Study limitations

Our study has several limitations. Firstly, PI measurement is quite sensitive to patient movement and could also be affected by several factors such as stress and anxiety that can induce sympathetic activation, which in turn induces peripheral vasoconstriction. Secondly, we did not measure peripheral and core temperature changes during surgery. Another limitation was the possibility of post-anaesthetic tremor mimicking shivering which may be caused by inadequate pain management. Despite these limitations, we were able to demonstrate that baseline PI was correlated with incidence and degree of shivering after spinal anaesthesia for caesarean delivery.

Conclusion

In conclusion, this study demonstrates that preoperative PI measured by pulse oximetry correlated with the incidence and degree of post-anaesthetic shivering in caesarean delivery under spinal anaesthesia, and a preoperative PI cut-off point of 4.2 could be used to identify patients at risk for post-anaesthetic shivering. PI may be a useful tool to predict post-anaesthetic shivering during spinal anaesthesia for patients undergoing caesarean delivery in everyday practice.

No competing interests declared.

ORCID iD

Arie Utariani https://orcid.org/0000-0002-1438-2447

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