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ORIGINAL RESEARCH OBSTETRIC ANESTHESIA

Pulse oximetry-based perfusion index as a non-invasive indicator of systemic hemodynamics during spinal anesthesia in cesarean delivery

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ABSTRACT

Background & Objectives: Placental perfusion is not autoregulated and is susceptible to effects of spinal anesthesia (SA) induced hypotension. The perfusion index (PI) is a non-invasive marker of peripheral vascular tone, and a higher PI indicates increased risk of hypotension following SA. This study aims to establish preoperative baseline PI in our local population and its correlation with incidence of intraoperative hypotension.

Methods: This prospective observational study recruited 35 parturients who underwent elective lower segment cesarean section (LSCS). Preoperatively, baseline heart rate (HR), systolic blood pressure (SBP), mean arterial pressure (MAP) and PI were documented. SA was performed with 8 to 10 mg of injection bupivacaine 0.5% (hyperbaric) at L3–L4 interspace followed by co-loading with 1 L Hartmann solution. Hypotension was defined as SBP less than 80% of baseline or less than 90 mmHg. A bolus of phenylephrine 50 µg was given as rescue medication to treat the hypotension. Intraoperatively, degree of decrease in SBP, MAP and HR, as well as the amount of phenylephrine required was recorded every minute until delivery of the baby and 3 min thereafter.

Results: The correlations between parturients' baseline PI with the degree of decreases in systolic and mean arterial pressure ($r = 0.81$, $P < 0.001$ and $r = 0.76$, $P < 0.001$, respectively) and phenylephrine requirement ($r = 0.761$, $p < 0.005$) were recorded. This study identified that the patients with cut-off PI value of 3.2 were at higher risk for SA induced hypotension with a sensitivity of 85.9% and a specificity of 87.5% ($P = 0.001$).

Conclusion: The patients with baseline cut-off perfusion index value of more than 3.2 were at higher risk for spinal anesthesia induced hypotension in elective cesarean section.

Abbreviations: CO - cardiac output; LSCS - lower segment cesarean section MAP - mean arterial pressure; PI - perfusion index; SA - spinal anesthesia

Keywords: Hypotension; Pulse Oximeter; Perfusion Index; Spinal Anesthesia; Cesarean section;

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1. INTRODUCTION

Spinal anesthesia (SA) is currently preferred method to provide adequate anesthesia and a moderate degree of maternal satisfaction for cesarean delivery.[1] SA causes immense sympathectomy, accompanied by a reduction of arterial sympathetic tone and with the addition of aortocaval compression in supine position, these will lead to a reduction of cardiac output (CO), with a high incidence of hypotension after SA.[2]

As placental blood flow is not autoregulated and is dependent upon the parturients mean arterial pressure (MAP), prevention and/or prompt treatment of hypotension remains paramount for better perioperative care. In predicting parturients at higher risk of postspinal hypotension, the anesthetists can be ready to offset the effects by use of vasopressors and co-loading with crystalloids.[3]

Perfusion index (PI) is defined as the ratio of pulsatile blood flow to the non-pulsatile blood in peripheral vascular tissue and the value ranges between 0.02% and 20%. PI determines changes in peripheral vasomotor tone, derived from non-invasive pulse oximeter. Parturients with high baseline PI are expected to have lower peripheral vascular tone and hence are at higher risk of developing hypotension following SA.[4,5] There has been limited data with regards to the baseline cut-off value of PI in our local population in Malaysia.

We aimed to establish a baseline PI in our local population as an indicator for the prediction of the development of hypotension after SA in elective LSCS. The primary objective being to evaluate the correlation between baseline PI and the incidence of postspinal hypotension.

2. METHODOLOGY

The prospective observational study was conducted between March 2018 to May 2018 in Hospital Tengku Ampuan Afzan, Kuantan, Pahang, Malaysia. Approval for the study was obtained from Medical Research & Ethics Committee (MREC) of National Medical Research Register (NMMR) (Code: NMRR-17-2211-37825) and Research Ethics Committee (Human) (JEPeM) of Universiti Sains Malaysia (JEPeM Code: USM/JEPeM/17100561). Informed written consent was obtained from every participant in the study. We included 35 parturients undergoing cesarean delivery consecutively during this time.

The sample size of this study was based on a sample size of two studies by Toyoma and Frolich respectively, by measuring the correlation coefficient at the desired power of 0.8 and two-tailed α of 0.05.[4,6] The power of 80% was accepted as the level of significance.

Parturients with pregnancy induced hypertension, diabetics on insulin, preeclampsia, cardiovascular disease, BMI > 35 kg/m^2, any contraindication for spinal anesthesia and placenta previa were excluded from this study.

Each parturient was kept nil by mouth for solid food for 6 h and for clear fluids for 2 h before surgery with maintenance fluid as standard practice. Preoperatively, parturient was attached to standard monitoring. Electrocardiography, automated NIBP, and pulse oximetry (SpO_2) was performed for baseline values and intraoperative monitoring. The pulse oximeter probe (Mashimo Radical 7; Masimo Corp., Irvine, CA, USA) was attached to the left index finger for all parturients in this study. Following baseline parameters were recorded; heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), oxygen saturation (SpO_2), and perfusion index (PI).

Parturient had intravenous (IV) access established with 18G cannula. SA was performed under aseptic technique in the sitting position using spinal needle Pencan 25G or 27G by an anesthesiologist not involved in the study. A standard dose of 8-10 mg of heavy bupivacaine 0.5%, 0.1 mg morphine, and 20 µg fentanyl was given at L3/L4. During intrathecal injection, co-loading was done with a fixed volume of IV one-liter Hartmann solution. Immediately after SA, parturient was returned to the supine position. Oxygen supplement 3 L/min was routinely given to all parturient as per our institutional standard practice. The level of sensory block was checked 5 min after the SA with a cold swab. If a T6 sensory block level was not achieved, these parturients were withdrawn from the study and managed according to institutional protocol.

Postspinal hemodynamic monitoring was done at one-minute intervals until delivery and then every 3 min until the end of the operation. Hypotension was defined as SBP < 80% of baseline or < 90 mmHg. A bolus of phenylephrine 50 µg was given as rescue medication, keeping the decrease within < 25% of the baseline value. Bradycardia was defined as HR < 55 bpm and treated with an IV bolus of 0.6 mg atropine.

A bolus of 5 IU oxytocin was given once the anterior shoulder of the baby was delivered and continued with

Table 1: Demographic characteristics (n = 35).

Variables	Mean ± SD or N (%)
Age (y)	34.03 ± 5.72
Race	
Chinese	4 (11.4)
Indian	3 (8.60)
Malay	25 (71.4)
Others	3 (8.60)
Gravida	3.74 ± 2.15
Parity	2.26 ± 1.85
Indications	
2 previous scars	8 (22.9)
3 previous scars	1 (2.9)
Breech presentation	9 (25.7)
Macrosomic baby	6 (17.1)
Refused trial of Scar	6 (17.1)
Severe oligohydramnios	1 (2.9)
Transverse lie	1 (2.9)
Unstable lie	3 (8.6)
Height (cm)	156.11 ± 5.16
Weight (kg)	69.26 ± 9.78
Gestational age (weeks)	38.31 ± 0.63
Hemodynamic data	
Baseline SBP (mmHg)	125.89 ± 10.91
Baseline MAP (mmHg)	91.49 ± 11.57
Baseline HR (beats/min)	95.0 ± 12.52
Baseline PI (ratio)	4.27 ± 1.97

PI = perfusion index

an infusion of 40 IU over 6 h after delivery of the placenta.

2.1. Statistical analysis

The data analysis was done using SPSS version 20. The descriptive data was expressed as mean ± standard deviation (SD) unless otherwise stated. Simple linear regression analysis with Spearman's rank correlation coefficient was done to assess the correlation between baseline PI with other parameters. Spearman correlation was done for non-normally distributed data for correlation analysis. A Receiver Operating Characteristic (ROC) curve was obtained for baseline PI compared with the hypotension episodes. $P < 0.05$ was considered statistically significant.

3. RESULTS

A total of 35 parturient were recruited for this study. None was withdrawn from the study. Parturients demographic parameters are presented in Table 1. The mean of baseline PI was 4.27 ± 1.97 (Table 1).

The percentage decrease from baseline was significant for SBP ($r = 0.81$, $P < 0.001$); and for MAP ($r = 0.76$, $P < 0.001$) and correlated with baseline PI as well (Table 2). The ROC analysis revealed that baseline PI is clinically a valid marker in detecting parturient at risk for hypotension. Based on the area under the curve (AUC) of the ROC curve; the area showed was 0.90 (95% CI: 0.80, 1.00, $P < 0.001$) suggesting of excellent performance (Figure 1). The baseline PI cut-off point that predicted hypotension as determined by the ROC analysis was 3.2 with a sensitivity of 85.19% [95% confidence interval (CI) 58–95%], a specificity of 87.50% (95% CI 57–98%), a positive predictive value of 65.7%, and a negative predictive value of 20% (Figure 1, Table 3).

Phenylephrine requirement correlated with baseline PI ($r = 0.761$, $P \leq 0.005$). Further analysis done based on PI cut-off value of 3.2 reveals that mean phenylephrine requirement for PI < 3.2 group was 4.55 µg while mean phenylephrine requirement for PI > 3.2 group was 147.5 µg (Figure 2). Concurrently, parturient with baseline PI > 3.2 had more significantly decreased SBP and MAP within 5 min after SA than those with baseline PI < 3.2 ($P < 0.001$).

Table 2: Correlation changes SBP and MAP with related variables (n=35)

Variables		% SBP decrease		% MAP decrease	
		r	P-value	*r*	P-value
Demographic characteristics	Age	0.33	0.054	0.24	0.160
	Height	-0.17	0.324	-0.08	0.649
	Weight	0.27	0.114	0.22	0.211
Obstetric characteristics	Gravity	0.15	0.380	0.20	0.253
	Parity	0.22	0.198	0.30	0.078
	Gestational age	0.21	0.231	0.14	0.429
Baseline parameters	HR	0.18	0.315	0.14	0.413
	SBP	0.46	0.006[a]	0.44	0.008[a]
	MAP	0.59	< 0.001[a]	0.66	< 0.001[a]
	PI (ratio)	0.81	< 0.001[a]	0.76	< 0.001[a]

[a] *correlation is significant at 0.05 level; PI = perfusion index*

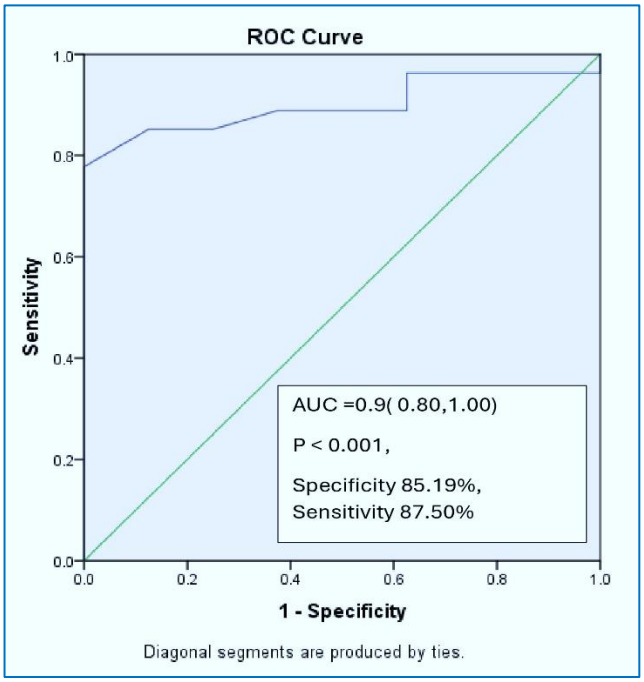

Figure 1: ROC curve PI as marker for hypotension. The optimal cut-off value for predicting the incidence of hypotension in PI was 3.2 based on area under the ROC curve (AUC)

4. DISCUSSION

The PI is a non-invasive, continuous, and easy to use parameter, derived from a pulse oximeter, that can be used as an additional hemodynamic parameter to predict hypotension, as demonstrated by this study and another study done in Japan.[4] Other non-invasive parameters like baseline heart rate, parturient height and weight were unable to predict the incidence of hypotension, even though these have been reported by several other studies.[6,7]

We found that baseline PI correlates with the percentage decrease in SBP and MAP after SA. In this study, the cut-off point for higher and lower baseline index was determined to be 3.2, based on the ROC analysis shown, which is different from a previous study of 3.5.[8] This discrepancy was attributed to methodological differences such as preloading with 500 ml of hydroxyethyl starch before SA and spinal-epidural technique used by Toyama et al.[4] Study by Singh et al. has even reported that a cut-off point of 3.8 to cause a decrease in SBP and MAP after SA. They reported a sensitivity of 79.07% and specificity of 72.73% which is much lower than our findings of 84.19 and 87.5% respectively.[9]

Likewise, previous study also demonstrated that higher baseline PI was more likely to have a more significant percentage of the drop in SBP and MAP. Even though a degree of hypotension after administration of SA for cesarean delivery is common and anticipated, those with lower PI are shown to be less affected.[8] This could be explained by PI reflects the peripheral vascular tone and its dependency on sympathetic activity, hence manage to predict the risk of developing hypotension where a decrease in peripheral vascular tone will be accompanied by compensatory dependence on sympathetic vasoconstriction.[4]

There was also a correlation noted between the requirement of phenylephrine and the baseline PI. In this study, all parturients with baseline PI > 3.2 required phenylephrine to maintain SBP, while several in group baseline PI < 3.2 did not require phenylephrine and managed to maintain the SBP with initial fluid loading and left lateral tilt; and those who needed did not require high dosage of phenylephrine to maintain SBP post-spinal. Again, due to the higher degree of hypotension in baseline PI > 3.2 group, there was higher dosage of phenylephrine required. We eliminated the potential hypovolemia secondary to reduced venous return due to pooling of blood and mechanical obstruction by gravid uterus that might lead to hypotension by adequately giving fluid co-loading after SA with parturient at a left lateral tilt.

We also found out there first few doses of phenylephrine were administered earlier to those with higher baseline PI, concurring with the earlier finding. In this study, the first boluses of phenylephrine were at the highest within 5 min post-SA for both groups; however, the number of boluses was higher in baseline PI > 3.2 group. We determined that 5 min postspinal was the critical time of vasodilation to occur because of SA, but this effect can be minimized by adequate fluid loading and managing the adverse effect of aortocaval compression, however the compensatory mechanism much

Table 3: Proportion of hypotension based on SBP with baseline PI (n = 35)

Variable	Baseline PI		P-value
	< 3.2	> 3.2	
Hypotension based on SBP			< 0.001**
No	7 (20.0)	1 (2.9)	
Yes	4 (11.4)	23 (65.7)	

*Data shown as n (%); SBP = systolic blood pressure, PI = perfusion index, **Pearson chi-square*

depends on sympathetic vasoconstriction, thus phenylephrine is required as necessary.

The true clinical value in using baseline PI is that we recognize that the placenta is not autoregulated. In certain population of cases, the fetal wellbeing may be affected, if they have limited reserve such as cases of placental insufficiency in preeclampsia or absent end diastolic flow. By knowing ahead of time if the parturient is at risk of hypotension, this can direct our clinical vigilance and give quality care at preventing the hypotension from happening. As anesthetist this can be achieved by co-loading, starting of vasopressor infusions early and lateral tilt.[10]

Much new research is being done to determine the association of PI with other outcomes of LSCS such as neonatal outcome and maternal blood loss postoperatively. PI may be affected by factors such as movement, temperature, and anxiety level, which can induce sympathetic activation.[11,12] Even so, the vascular tone is not only regulated by the sympathetic pathway, but also endothelial pathway. Hence, careful assessment and averaging value for baseline PI still must be done with the utmost care, as there is a possibility of different interpretation in different clinical circumstances.

5. LIMITATIONS

We did not include a variety of patients such as emergency LSCS, for whatever indications, parturients with gestational diabetes and hypertension, parturients with underlying cardiovascular heart diseases or other underlying diseases and conditions that may affect both endothelial and sympathetic compensation after SA.

It could be worth to see if there were different cut-off points if there parturient were included.

6. CONCLUSION

In conclusion, the baseline cut-off perfusion index value of more than 3.2 were at higher risk for spinal anesthesia-induced hypotension in elective LSCS. It is a valid marker with good sensitivity and specificity values. Hence, the adoption of routine perfusion index monitoring preoperatively during cesarean delivery under spinal anesthesia is recommended.

7. Data availability

The numerical data generated during this research is available with the authors, and can be examined on a reasonable request.

8. Acknowledgement

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9. Conflict of interest

The study utilized the hospital resources only, and no external or industry funding was involved.

10. Authors' contribution

All authors contributed in the conduct of this study, data collection, literature search, statistical analysis and manuscript preparation. All authors approve the final draft.

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