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Regional tissue oxygen saturation as a predictor of post-spinal anesthesia hypotension for cesarean delivery

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Since the discovery of neuraxial blockade, spinal anesthesia has been frequently used for cesarean section. According to an international consensus statement on hypotension management, Kinsella *et al*[1] reported the incidence of post-spinal anesthesia hypotension in parturient women to be as high as 70% to 80%. Post-spinal anesthesia hypotension is mainly caused by sympathetic vasomotor block, which results in reduced systemic vascular resistance, venous pooling in capacitance vessels, and decreased cardiac output. Severe hypotension may lead to maternal and fetal adverse events. Undesirable maternal hypotension may contribute to reduced uterus blood flow resulting in decreased placental perfusion and fetal hypoxia leading to acute fetal acidosis. Pregnant women having a positive preoperative stress test were associated with an increased risk of post-spinal anesthesia hypotension during cesarean delivery.[2] However, the sensitivity of the stress test for predicting post-spinal anesthesia hypotension was only 69%.[2] In clinical practice, non-invasive, reliable, and readily available techniques are still much in need to predict the incidence of hypotension after spinal anesthesia as well as to improve the management of spinal anesthesia-induced hypotension for cesarean delivery.

Near-infrared spectroscopy (NIRS) is a non-invasive technique that allows continuous assessment of tissue oxygen saturation index (rSO_2).[3] NIRS measures blood oxygenation in the microvasculature, utilizing near-infrared light at wavelengths that are absorbed by hemoglobin to provide real-time adequacy of perfusion data. Peripheral nerve block could induce local vasodilation and increase subcutaneous tissue oxygen saturation via sympathetic blockade.[4] Recent work suggested that increased subcutaneous tissue oxygen saturation in the middle anterior thigh could predict the success of femoral nerve block.[5] However, the potential role of this clinically available application for predicting hypotension after spinal anesthesia remained uncertain. Changes of rSO_2 in the middle anterior thigh after spinal anesthesia for cesarean delivery have not previously been researched. We hypothesized that rSO_2 would reflect the vasomotor tone and allow identification of parturients at a higher risk of post-spinal anesthesia hypotension. The primary aim of this study was to determine the changes of rSO_2 measured by NIRS after spinal anesthesia and to investigate whether rSO_2 could predict post-spinal hypotension in parturients.

This prospective study obtained ethical approval from the local ethics committee (No. S151), and written informed consent was provided by all parturients. This study enrolled 97 patients aged 20 to 40 years, American Society of Anesthesiologists (ASA) physical status I–II, gestational age of 36–41 weeks, who were scheduled for elective cesarean delivery under spinal anesthesia from January 2019 to November 2019 at Union Hospital, Tongji Medical College, Huazhong University of Science and Technology. Exclusion criteria were: placenta previa, pre-eclampsia, pregnancies complicated with cardiovascular or cerebral vascular diseases, gestational diabetes, body mass index (BMI) ≥ 40, and contraindications to spinal anesthesia. The two sensors used were connected to a four-channel NIRS (INVOS 4100; Covidien, Mansfield, MA, USA) and were applied to the patient's middle anterior thigh both in the left and right limbs. Before spinal anesthesia, baseline rSO_2 data in the bilateral lower limbs were obtained.

Upon arrival in the operating room, standard monitoring with non-invasive blood pressure, heart rate, and oxygen

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saturation were established. Baseline systolic pressure and diastolic pressure were recorded in the supine position. All parturient women received oxygen by nasal cannula at 2 L/min. Patients were turned to right lateral decubitus position for combined spinal and epidural anesthesia in midline approach. The epidural needle was inserted through ligamentum flavum to the epidural space between the L3 and L4 spinous processes. The spinal needle was advanced through the epidural needle to the subarachnoid space for free-flowing clear cerebrospinal fluid. Two milliliters of 0.6% ropivacaine were intrathecally injected over 30 to 60 s. After removal of the spinal needle, the epidural catheter was placed at a depth of 4 to 5 cm into the epidural space. After epidural catheter was secured, the patient was immediately shifted into the supine position. Cold sensory tests were performed to assess the sensory block level. If the extent of sensory block was not achieved at Th6 level, an epidural dose of 2% lidocaine was injected and these patients were then excluded. The non-invasive blood pressure, heart rate, and rSO_2 values were recorded at 1 min as from spinal anesthesia completion up to the delivery of the fetus. The above measurements were then documented at 3-min intervals after childbirth.

Post-spinal anesthesia hypotension was defined as a systolic pressure of <90 mmHg or as a significant drop of >25% of the baseline value. In the case of post-spinal hypotension, a standardized protocol was given. Intravenous ephedrine was injected if the heart rate descended <60 beats/min followed by hypotension. In case the heart rate remained >60 beats/min despite hypotension, intravenous phenylephrine was administered. Episodes of hypotension were recorded as from completion of spinal anesthesia up to childbirth.

Statistical analyses were performed with SPSS for Windows (Version 22.0; SPSS, IBM Corp., NY, USA). All line graphics were constructed using GraphPad Prism version 6.01 for Windows (Graph Pad Software, San Diego, CA, USA). Normally distributed variables were expressed as mean ± standard deviation, and intergroup comparisons were performed using an independent sample t test. The non-normal distributed data were presented as median (range) and were analyzed using the Mann–Whitney U test. Categorical data were reported as numbers (percentages) and analyzed using the Chi-square test. A P value of <0.050 was taken as statistically significant. The receiver operating characteristic (ROC) curves were generated to evaluate the diagnostic power of rSO_2 for predicting post-spinal anesthesia hypotension. The optimal cut-off value was determined by Youden index, which provided equally weighted sums of the true positive rate and true negative rate.

In this study, five parturients were excluded due to inadequate spread of sensory block. Out of 92 patients, 45 (48.9%) developed post-spinal anesthesia hypotension. There was no significant difference in baseline characteristics (age, height, weight, gestational age, and duration of surgery) between hypotension and non-hypotension groups. The sensory block level was Th4 (Th2–Th6) in the hypotension group and Th5 (Th3–Th6) in the non-hypotension group, which was not significantly different ($Z = -1.451$, $P = 0.158$). The neonatal body weight was similar in both groups (3.2 ± 0.8 *vs.* 3.0 ± 0.9 kg, $t = 1.508$, $P = 0.133$). The baseline rSO_2 values of the left side in post-spinal hypotension and non-hypotension patients were 82.5 ± 4.8 % and 85.9 ± 4.4 %, respectively, which were significantly different ($t = -3.596$, $P = 0.001$) [Supplementary Table 1, http://links.lww.com/CM9/A672]. Compared with the non-hypotension group, the baseline rSO_2 value of right side was significantly lower in the hypotension group (81.6 ± 5.8 *vs.* 83.8 ± 4.0, $t = -2.138$, $P = 0.035$). At 3-min intervals after spinal anesthesia, parturients in the hypotension group were associated with significantly lower rSO_2 values of the left side, compared to those in the non-hypotension group (82.8 ± 5.0 *vs.* 88.2 ± 3.3, $t = -6.198$, $P < 0.001$). Furthermore, the average rSO_2 values of the right side after 3-min post-spinal anesthesia were 81.8 ± 5.7 in hypotension patients and 85.2 ± 3.6 in non-hypotension parturients ($t = -3.403$, $P = 0.001$).

As shown in Figure 1A, baseline rSO_2 value in the left side could predict post-spinal anesthesia hypotension with the area under the receiver operator characteristic curve (AUC) of 0.723. According to the ROC analysis, the sensitivity and specificity were 81% and 73%, respectively, with the optimal cut-off value of 84.50. Our results also showed that the AUC for baseline rSO_2 value in the right side was 0.628 with a sensitivity of 72% and a specificity of

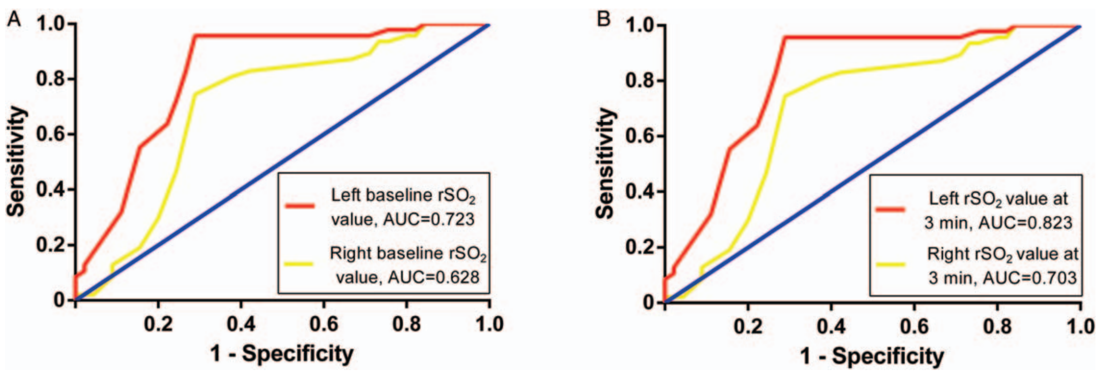

Figure 1: ROC curves of rSO_2 levels for predicting post-spinal anesthesia hypotension. (A) Baseline rSO_2 value for the prediction of post-spinal hypotension; (B) The rSO_2 value at 3-min interval after subarachnoid block for the detection of post-spinal hypotension. AUC: Area under the receiver operator characteristic curve; ROC: Receiver operating characteristic; rSO_2: oxygen saturation index.

64%. The optimal threshold cut-off value for the right baseline rSO_2 measurement was 82.50.

The diagnostic power of rSO_2 value at 3 min after spinal anesthesia for predicting post-spinal anesthesia hypotension is illustrated in Figure 1B. The rSO_2 value in the left side at 3-min intervals after spinal anesthesia was able to distinguish post-spinal hypotension, with the sensitivity and specificity of 96% and 71%, respectively. The AUC was 0.823 at a cut-off value of 84.50. The diagnostic performance of the rSO_2 value in the right side at 3-min intervals after spinal anesthesia showed an AUC of 0.703 with a cut-off value of 84.50. The sensitivity and specificity were found to be 74% and 71%, respectively. Baseline rSO_2 might be used to predict the incidence of post-spinal anesthesia hypotension during cesarean delivery with the AUC of 0.723 in the left side and 0.628 in the right side (An AUC value of 0.70–0.79 shows acceptable prediction ability). The rSO_2 value at 3 min after spinal anesthesia showed stronger predictive ability with the AUC of 0.823 on the left side and 0.703 on the right side (An AUC value of 0.80–0.89 corresponds to excellent prediction ability).

To our knowledge, this was a rare study as it investigated the ability of rSO_2 in the middle anterior thigh measured by NIRS technique in predicting post-spinal anesthesia hypotension during cesarean delivery. Our results demonstrated a high sensitivity and specificity of rSO_2 value in the left side at 3-min intervals after spinal anesthesia for predicting the incidence of spinal anesthesia-induced hypotension. However, pre-anesthetic baseline rSO_2 value might have more immediately practical and clinical value for anesthesiologists to prevent hypotension after spinal anesthesia in parturients. ROC analyses indicated that the optimal threshold cut-off value of rSO_2 in the left side was the same initially and 3 min after spinal anesthesia. A reliable and objective indicator of post-spinal hypotension during cesarean delivery is clinically significant in protecting against maternal decreased blood pressure promptly. This valuable indicator can assist us in the early administration of vasopressors for the prevention and management of maternal hypotension post-spinal anesthesia during cesarean section, thus favoring better fetal and maternal outcomes. Compared to other assessment tools, NIRS is clinically available and easily transportable with a friendly interactive interface and highly efficient for data acquisition. NIRS reflects blood oxygenation and perfusion distribution in the microvasculature with multi-sensor monitoring and provides continuous and real-time perfusion data. The sensors are user and patient-friendly, making monitoring of ischemic threats to the brain and body tissues safe and easy, thus guiding clinicians' assessment and intervention accordingly. However, the potential disadvantages with routine use of NIRS monitoring are the high costs of single-use optode and limited spatial resolution. NIRS technique has been used widely to evaluate cerebral blood oxygenation changes but to a lesser extent in regional oxygen saturation of the anterior thigh. In the present study, the use of regional oxygen saturation of the left anterior thigh as an excellent predictor with high sensitivity in evaluating post-spinal hypotension and practical advantages of NIRS technique for parturients were clarified.

In maternal pregnancy, the blood flow to the uterus from the pelvic is increased and aorto-caval compression due to the pregnant uterus and pelvic contributes to hemodynamic changes associated with spinal anesthesia. Dextrorotation of the uterus in pregnancy is common, and left uterine displacement in the pre-delivery phase may help in minimizing hemodynamic changes after subarachnoid block. Future studies are warranted to evaluate the correlation between rSO_2 in pregnancies with left uterine displacement and the incidence of post-spinal hypotension during cesarean section. There are some limitations to our study. We arbitrarily assessed rSO_2 value and blood pressure at 3-min intervals after fetal childbirth instead of monitoring at each minute.

In conclusion, NIRS measurement of rSO_2 in the lower limb represents a useful diagnostic tool to predict post-spinal anesthesia hypotension in patients undergoing cesarean delivery. A value for $rSO_2 > 84.50$ is a good predictor of post-spinal hypotension after subarachnoid block in parturient.

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Conflicts of interest

None.

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