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ORIGINAL ARTICLE

Effects of maternal supplementary oxygen on the newborn for elective cesarean deliveries under spinal anesthesia

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Abstract
Purpose The aim of this investigation was to determine whether supplementary oxygen provided by either nasal cannula or face mask versus room air might affect fetal oxygenation during elective cesarean section under spinal anesthesia by assessing maternal and neonatal regional cerebral oxygenation (rSO_2) with a cerebral oximeter.
Methods Ninety parturients were randomly allocated into three groups: two groups received 5 L/min oxygen by either nasal cannula (Group NC, $n = 30$) or face mask (Group FM, $n = 30$), respectively, and the third group was allowed to breathe room air (Group RA, $n = 30$). After maternal mean arterial pressure, heart rate and peripheral oxygen saturation had been monitored, rSO_2 was determined by cerebral oximeter. Umbilical artery (UA) and venous (UV) blood samples were collected for blood gas analysis. Neonatal rSO_2 and Apgar scores were recorded.
Results The mean maternal rSO_2 which was recorded 3 and 5 min after administration of the spinal block in Group FM was lower than that of Group NC ($p = 0.033$ and 0.042, respectively). Neonatal rSO_2, UA pH, UV pH and UA base excess (BE) were lower in Group FM than in the other groups ($p < 0.05$). The Apgar score (1 min) in Group FM was lower than that of Group RA ($p = 0.046$).
Conclusion The effect of maternal supplementary oxygen on the newborn has been demonstrated by a cerebral oximeter monitor and supported by umbilical cord blood gas analysis and Apgar scores.

Keywords Cesarean section · Elective anesthetic technique · Spinal block · Oxygen · Supplementary monitorization · Regional cerebral oxygen

Introduction

The different effects of supplementary oxygen administration have been extensively investigated in parturients scheduled to undergo either elective or emergency cesarean section (C/S) under regional anesthesia [1–3]. Following publication of results in 1982 that demonstrated the effect of oxygen transfer from mother to the fetus during C/S under epidural anesthesia [4], supplementary oxygen was considered to be unnecessary in healthy women undergoing elective C/S under spinal anesthesia [5].

According to the Standards for Basic Anesthetic Monitoring approved by The American Society of Anesthesiologists (ASA), a quantitative method of assessing oxygenation, such as pulse oximetry, should be used in adults receiving either regional or general anesthesia for adults [6]. Additionally, optical methods, such as pulse oximetry and near infrared spectroscopy (NIRS), have been made applicable to fetus and proven to be helpful tools for fetal surveillance during labor by the perinatologists [7, 8].

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Cerebral oximetry, which is a NIRS technology that estimates real-time measures of brain oxygenation (regional cerebral oxygen saturation: rSO_2) both non-invasively and continuously without requiring pulsatility and flow, has been utilized in different types of surgical anesthesia except obstetrics [9–11]. To the best of our knowledge, NIRS has not been used to show the effect of maternal supplementary oxygen on fetal oxygenation for neonatal monitorization even though it might be a faster clinical evaluation than both the umbilical cord blood gas analysis and Apgar scores in the obstetric anesthesia setting. Therefore, the aim of this prospective randomized study was to determine whether maternal oxygenation administration by either nasal cannula or simple face mask versus room air might affect fetal oxygenation during elective C/S under spinal anesthesia. Maternal and neonatal rSO_2 was determined with a cerebral oximeter, and the results of umbilical cord blood gas analysis and Apgar scores were obtained.

Methods

After approval of the Institutional Ethic Committee and written informed consent from each patient, 90 ASA class I or II parturients between 37 to 42 weeks of gestation with singleton vertex pregnancy scheduled for elective cesarean delivery under spinal anesthesia were recruited. After aspiration prophylaxis with intravenous (IV) metoclopramide 10 mg and ranitidine 50 mg 30 min before the operation, approximately 15 mL/kg of Ringer's lactate solution was administered within 15 min before administration of the spinal block. With the patient in the sitting position, the spinal block was performed with a 25 gauge *pencan* spinal needle with midline approach between L3–4 intervertebral space followed by the intrathecal injection of 12 mg of 0.5% hyperbaric bupivacaine, fentanyl 10 μg and morphine 100 μg with the bevel of the spinal needle directed cephalad. Immediately after administration of the spinal block, parturients were randomly allocated into three groups according to computer generated numbers: two groups were administered oxygen at a flow rate of 5 L/min by either nasal cannula (Nasal Oxygen Cannula; Bıçakcılar, Istanbul, Turkey; Group NC, $n = 30$) or face mask (Oxygen Mask–adult; Plasti-med, Istanbul, Turkey; Group FM, $n = 30$) and the third group was allowed to breathe room air (Group RA, $n = 30$). Inspired oxygen fraction (FiO_2) of at least 0.30, 0.32 and 0.21 was targeted in Groups FM, NC and RA, respectively. After routine maternal mean arterial pressure (MAP), heart rate (HR), ECG and peripheral oxygen saturation (SpO_2) monitorization, maternal rSO_2 was determined by cerebral oximeter (Near infrared spectroscope model INVOS 5100; Somanetics, Troy, MI) through bilateral (right & left) adult frontal sensors.

The INVOS 5100 is a two-channel (R + L) NIRS cerebral oximeter that automatically registers which sensor it is connected to and uses sensor-dependent algorithms for the calculation of rSO_2 [12]. The adult (>40 kg) and pediatric versions of the INVOS 5100 somasensor, which are for single use, have an adhesive layer attached for rSO_2 determination.

All maternal parameters were recorded and documented at (0, baseline control), 1, 3, 5 and 8 min consecutively after administration of the spinal block until delivery (time of umbilical cord clamping). In order to establish individual baseline (control) rSO_2, rSO_2 was monitored at least 5 min before administration of the spinal block to obtain an arithmetic mean of the five measurements to record the control value.

Aortocaval decompression was provided by tilting the operating table approximately 15° to the left immediately after administration of the spinal block to avoid supine hypotension. Maternal hypotension was defined as a decrease >20% of baseline MAP, and HR <50 beat/min was considered to be bradycardia. In the event that hypotension and/or bradycardia were detected, IV ephedrine 10 mg and atropine 0.5 mg were administered, respectively, and the ephedrine and atropine requirements recorded. Surgery was allowed when the sensory block reached to at least T5 bilaterally.

After delivery of the newborn, umbilical artery (UA) and umbilical venous (UV) blood samples were collected for pH measurement and blood gas analysis [PO_2, PCO_2 and base excess (BE)]. Additionally, neonatal rSO_2 was monitored by cerebral oximeter through bilateral (right & left) pediatric frontal sensors and recorded at 1-min intervals during the first 5 min post-delivery by an anesthesiologist. Apgar scores (1 and 5 min) were assessed by a pediatrician. The pediatrician was blinded to the study protocol (either absence or presence of maternal supplementary oxygen administration via face mask or nasal cannula). A junior anesthesiology resident was asked to record NIRS data, while the staff anesthesiologist responsible for the study was taking care of the patient. Maternal and neonatal demographic properties and time intervals from spinal block to skin incision (onset of surgery), from skin incision to delivery and from uterus incision to delivery (U–D) were recorded.

Statistical analysis

From our previous study [9], baseline maternal rSO_2 from the right and left sensors were 61.3 ± 12.0 and 63.5 ± 11.4%, respectively. Power analysis showed that a sample size of 30 parturients in each group would yield 90% power to detect a 10% change in the rSO_2 with a type I error of 0.05.

The results were expressed as the mean ± standard deviation (mean ± SD) or as the number (n) where appropriate. Following descriptive statistics, comparisons among the three groups were performed with one-way analysis of variance (ANOVA) followed by the post hoc least significant difference (LSD) test in the case of significant differences. Comparisons within groups and two independent group comparisons were performed using the Wilcoxon test and t test, respectively. Friedman analysis of variance was used for multiple comparisons within the group followed by Wilcoxon test with Bonferroni correction in the case of significant differences. $p < 0.05$ was considered to be statistically significant.

Results

Demographics of the parturients, delivery time intervals, ephedrine and atropine requirements and the amount of ephedrine administered to treat hypotension were comparable among the groups (Table 1).

The demographic properties and 5-min Apgar score of the newborns were comparable among the groups ($p > 0.05$), whereas the 1-min Apgar score in Group FM was significantly lower than that of Group RA ($p = 0.046$; Table 2). Additionally, one newborn in each group had Apgar score 7.

The partial pressure of oxygen (PO_2) in the UA and UV blood samples was similar in all groups ($p > 0.05$). However, the mean UA pH, UV pH and UA BE were significantly lower in Group FM than in both of the other two groups ($p < 0.05$) (Table 3). Mean UA partial pressure of carbon dioxide (PCO_2) in Group FM was significantly higher than that in Group RA, whereas mean UV PCO_2 in Group FM was significantly higher than that in both Group NC and RA ($p < 0.05$) (Table 3).

The mean maternal SpO_2 recorded 3 and 5 min after administration of the spinal block was significantly higher in Group FM (99.5 ± 0.7 and 99.4 ± 0.9%, respectively) than in Group RA (98.0 ± 2.2 and 98.4 ± 1.1%, respectively) ($p < 0.001$) (data not shown). The mean maternal HR recorded 8 min after administration of the spinal block was significantly higher in Group FM (106.5 ± 26.8 beat/min) than in Group NC (89.2 ± 18.1 beat/min) ($p = 0.007$). In terms of blood pressure changes, the maternal MAP recorded 3 min after administration of the spinal block in Group FM (68.2 ± 17.9 mmHg) was significantly lower than that of Group RA (77.8 ± 16.9 mmHg) ($p = 0.039$).

The maternal and neonatal control rSO_2 recordings from left and right sensors were comparable among the groups. The mean maternal rSO_2 recorded 3 and 5 min after administration of the spinal block was significantly lower in Group FM than in Group NC ($p = 0.033$ and 0.042, respectively), but the rest of the rSO_2 recordings were comparable between the groups NC and RA (Fig. 1). The mean neonatal rSO_2 readings from the left and right sensors during the first 5 min after delivery were significantly lower in Group FM than in both of the other two groups ($p < 0.05$) (Fig. 2).

Discussion

Our results are the first to demonstrate that the effect of maternal supplementary oxygen on the fetus can be followed by monitoring neonatal cerebral oxygenation as well as by umbilical cord blood gas analysis and evaluation of Apgar scores during elective C/S under spinal anesthesia.

Table 1 Maternal demographic properties, time intervals until onset of surgery and delivery and ephedrine and atropine requirements of the parturients

Demographic and clinical variables	Group RA ($n = 30$)	Group NC ($n = 30$)	Group FM ($n = 30$)
Age (year)	31 ± 5	31 ± 5	32 ± 6
Weight (kg)	78 ± 10	76 ± 9	75 ± 9
Height (cm)	165 ± 4	164 ± 4	162 ± 3
Gestation (weeks)	38.2 ± 1.9	38.8 ± 0.9	38.5 ± 1.0
Spinal to skin incision (min)	11.3 ± 5.05	10.2 ± 4.9	11.7 ± 5.2
Skin incision to delivery (min)	4.0 ± 1.8	3.8 ± 1.2	4.5 ± 2.5
Uterus incision to delivery (min)	1.4 ± 0.7	1.1 ± 0.3	1.5 ± 1.1
Ephedrine (mg)	27.3 ± 21.7	31.2 ± 22.0	37.1 ± 30.6
Ephedrine requirement (yes/no) (n)	26/4	24/6	24/6
Atropine requirement (yes/no) (n)	1/29	1/30	3/27

Unless otherwise indicated, data are presented as the mean ± standard deviation (SD)

All parameters given in the table did not differ statistically among the groups

RA Room air, *FM* 5 L/min oxygen supplied through a face mask, *NC* 5 L/min oxygen supplied through a nasal cannula

Table 2 Demographic properties and Apgar scores of the newborns

Variables	Group RA ($n = 30$)	Group NC ($n = 30$)	Group FM ($n = 30$)	p value (FM vs. NC)	p value (FM vs. RA)
Birth weight (g)	3245 ± 619	3357 ± 349	3189 ± 476	NS	NS
Birth height (cm)	49 ± 2	49 ± 1	48 ± 2	NS	NS
Apgar 1 min	9.1 ± 0.6	9.1 ± 0.7	8.5 ± 1.7*	NS	0.046
Apgar 5 min	9.9 ± 0.2	9.9 ± 0.3	9.9 ± 0.4	NS	NS

Data are presented as the mean ± SD

NS Not significant

* $p < 0.05$ versus Group RA

Table 3 Umbilical cord blood gas analysis

Blood gas analysis	Group RA ($n = 30$)	Group NC ($n = 30$)	Group FM ($n = 30$)	p value (FM vs. NC)	p value (FM vs. RA)
UA pH	7.31 ± 0.063	7.29 ± 0.079	7.24 ± 0.096*$^{+}$	0.022	0.009
UA PO_2 (mmHg)	22.5 ± 9.6	23.7 ± 12.2	21.18 ± 7.16	NS	NS
UA PCO_2 (mmHg)	48.1 ± 11.7	51.4 ± 11.3	55.7 ± 10.9*	NS	0.018
UA BE (mmol/L)	−2.52 ± 2.07	−2.4 ± 2.78	−4.3 ± 3.2*$^{+}$	0.019	0.042
UV pH	7.35 ± 0.047	7.35 ± 0.063	7.29 ± 0.078*$^{+}$	0.017	0.006
UV PO_2 (mmHg)	31.3 ± 6.9	33.98 ± 8.18	30.8 ± 11.5	NS	NS
UV PCO_2 (mmHg)	40.4 ± 5.6	41.1 ± 7.1	46.08 ± 6.28 *$^{+}$	0.012	0.001
UV BE (mmol/L)	−3.27 ± 1.77	−3.18 ± 1.82	−4.8 ± 3.5	NS	NS

Data are presented as the mean ± SD

UA Umbilical artery, *UV*, umbilical vein, *PO_2* partial pressure oxygen, *PCO_2* partial pressure carbon dioxide, *BE* base excess

* $p < 0.05$ vs. Group RA; $^{+}$ $p < 0.05$ vs. Group NC

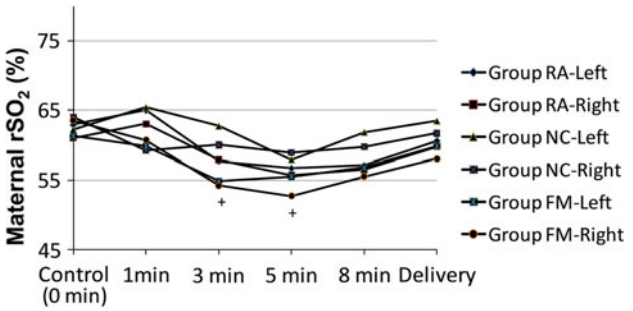

Fig. 1 Maternal regional cerebral oxygen saturation (rSO_2) readings from left and right sensors after spinal block until delivery (mean ± standard deviation). *Plus sign* (+) $p < 0.05$ vs. Group NC. *RA* Room air, *FM* 5 L/min oxygen supplied through a face mask, *NC* 5 L/min oxygen supplied through nasal cannula

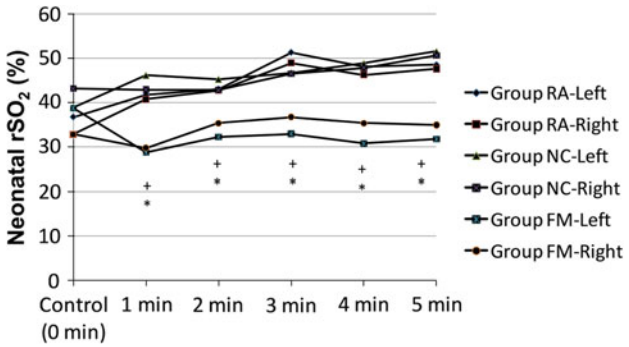

Fig. 2 Neonatal rSO_2 readings from the left and right sensors after delivery (mean ± SD). *Plus sign* (+) $p < 0.05$ vs. Group NC, *asterisk* (*) $p < 0.05$ vs. Group RA

We also found that the maternal rSO_2 was comparable without or without supplementary nasal oxygen. However, supplementary oxygen provided through a face mask at a flow rate of 5 L/min, which was estimated to correspond roughly to the fraction on inspired oxygen (FiO_2) ≅ 0.3, did not result in better neonatal oxygenation than oxygen delivery by nasal cannula (FiO_2 ≅ 0.32) or simply by breathing room air ($FiO_2 = 0.21$), based on neonatal rSO_2 monitorization. These results were supported by the results of the umbilical cord blood gas analysis.

Information on neonatal outcome can be partially provided from Apgar scores. Backe et al. [13] reported that Apgar scores did not differ between the groups in their study receiving an oxygen–air mixture via the Hudson style face mask providing $FiO_2 = 0.21$–0.25 or $FiO_2 = 0.40$–0.60. Similarly, Apgar scores were also found to be comparable when the groups receiving air were compared with the

group receiving 60% oxygen via a high-flow Venturi type face mask [1]. In contrast, we observed that the 1-min Apgar score in the FM group was significantly lower than that in the group receiving oxygen via nasal cannula and the group breathing room air; in these latter two groups, the highest Apgar score reached 5 min after delivery.

Umbilical cord blood gas analysis after delivery reflects the fetal condition immediately before delivery more objectively than the Apgar score, with UA blood gas measurements representing the fetal condition and UV measurements representing the maternal condition and uteroplacental gas exchange [14]. It has been reported that the Hudson-style face mask providing air at either $FiO_2 = 0.21–0.25$ or $FiO_2 = 0.40–0.60$ did not result in any significant differences in the UV PO_2 and UA BE compared with either supplementary oxygen (40%) or air provided by face mask and that oxygen supplied at 2 L/min by nasal cannula did not show any significant differences in the umbilical cord blood gas analysis among the three groups [5, 13]. However, Khaw et al. [1] reported that oxygen delivery by high-flow Venturi type face mask did result in a higher UA and UV PO_2, and UA and UV O_2 compared to the group receiving air, but that the pH results were similar. In our study, we demonstrated that UA and UV pH measurements and UA BE in the FM group were significantly lower than those in the group receiving oxygen via nasal cannula (NC) and those in the group breathing room air (RA). According to published data, the lower limit of normal UA blood pH may range from 7.02 to 7.18 [14]. The mean UA and UV pH measurements of the FM group in our study, which were 7.24 ± 0.096 and 7.29 ± 0.078, respectively, were considered to be normal. Additionally, base excess, which is known to be the most significant factor associated with neonatal morbidity, was also within normal limits, although it was significantly lower in the FM as well. In contrast to the results published by Khaw et al. [1], our results indicate that the partial pressure of oxygen in the UA and UV samples were comparable among the groups. One possible explanation may be related to the ability of the standard face mask or nasal cannula to provide comparable FiO_2 versus air in our study when compared to the high FiO_2 provided by the Venturi-type face mask versus air in the study of Khaw et al. [1].

Pulse oximetry is not only used for monitoring oxygen status in the mother, but it is also used to be a monitoring tool for intrapartum fetal oxygenation [15]. Based on 317 pulse oximetry measurements, Seelbach-Göbel reported that respiratory pCO_2 was positively correlated to time [8]. Our results are in agreement with those of Seelbach-Göbel [8]: we demonstrated that the UA PCO_2 in the FM group was significantly higher than that in the RA group, whereas the UV PCO_2 was significantly higher than that in both the RA and FC groups. The possible reason for high fetal $PaCO_2$ in the FM group was the hypotension requiring a larger amount of ephedrine although it was not significantly different among the groups, leading fetal acidemia and a low Apgar score when compared to the NC or RA groups in our study. Even if there were some rebreathing of CO_2 with the face mask application, parturients were likely to increase minute ventilation to maintain maternal $PaCO_2$.

The effect of general versus spinal anesthesia on cerebral oxygen saturation by NIRS was investigated in geriatric patients undergoing emergency surgical fixation of the neck of the femur [10]. In that study, spinal anesthesia was associated with a higher incidence of cerebral desaturation even though 3 L/min supplementary oxygen was administered by nasal cannula [10]. In parallel to that study, we recorded significantly low maternal rSO_2 readings in the FM group 3 and 5 min after administration of the spinal block; these were consistent with the significantly low neonatal rSO_2 results in the FM group that were recorded within 5 min after delivery. The neonatal cerebral desaturation that was observed with the face mask application was supported by the significantly lower umbilical cord blood gas analysis results. The main difference between our study and that of Hoppenstein et al. [10] was that the latter study comprised a geriatric patient population.

The effect of supplementary oxygen administration on the maternal and neonatal lipid peroxidation during C/S under spinal anesthesia is controversial. In a study carried out by Khaw et al. [2], supplementary oxygen supplied during elective C/S under spinal anesthesia resulted in increased O_2 transfer to the fetus associated with increased maternal and neonatal lipid peroxidation. However, in contrast to the results of a modestly increased fetal oxygenation associated with a concomitant increase in maternal and fetal oxygen-free radical activity by breathing high FiO_2, in another study by Khaw et al. [1], 60% oxygen administration during emergency C/S under regional anesthesia caused increased fetal oxygenation without increasing maternal and neonatal lipid peroxidation. These contradictory findings have been extensively reviewed by Van de Welde [16], resulting in the statement that supplementary oxygen in parturients should be used for emergency C/S but not for elective cases. Although we have not studied free radical activity, our data support the finding that administering modest FiO_2 via a face mask is more likely to change fetal oxygenation, which was evident by neonatal cerebral desaturation associated with low umbilical cord blood gas analysis results.

It has been reported that although the longer time interval from skin incision to delivery and U–D interval might possibly render parturients susceptible to an increased number of hypotension episodes, leading to a compromised fetus and, subsequently, newborn, no relationship was observed between MAP, HR and the

frequency of rSO_2 dips below baseline [10]. In contrast to these results, we observed similar delivery time intervals, but a significantly lower MAP was recorded 3 min after administration of the spinal block requiring ephedrine treatment, resulting in a higher HR 8 min after spinal block in the Group FM. These hemodynamic changes could be associated with the maternal and neonatal cerebral desaturation monitored by the near infrared cerebral oximeter. Therefore, these results in Group FM could be secondary to the ephedrine-induced beta adrenergic stimulation which is the most likely mechanism for the increased fetal acidosis. Our data are supported with umbilical cord blood gas analysis results, pH measurements and 1-min Apgar scores.

Face mask application time, incision to delivery time and/or U–D interval may play an important role on neonatal outcome. The mean face mask application time (18.8 min), skin incision to delivery time (8.8 min) and umbilical cord blood gas results have been reported to be similar between groups receiving air–oxygen (FiO_2 0.21–0.25) versus oxygen (FiO_2 0.40–0.60) [13]. In another study comparing 21, 40 and 60% maternal supplementary oxygen, no significant differences in the UV or UA blood gases, oxygen content or Apgar scores were found according to the subgroup analysis made between cases with and without prolonged U–D interval (>180 s) [3]. Despite similar oxygen application times, we observed significantly lower UA pH, UV pH and UA BE which were also confirmed by low neonatal rSO_2.

This is the first study to demonstrate that supplementary oxygen may cause FiO_2 changes and, consequently, may affect neonatal outcome as monitored by cerebral oximeter during elective C/S under spinal anesthesia. The maternal rSO_2, either without supplementary oxygen or with supplementary nasal oxygen, was demonstrated to be comparable. Additionally, supplementary oxygen supplied by face mask did not result in better neonatal oxygenation than the oxygen delivery by nasal cannula or even breathing room air. Based on these results, a specific obstetric population including parturients having high spinal block, longer uterine incision delivery time or consistent hypotension might benefit from supplemental oxygen, but we need to evaluate this need with a faster clinical testing, such as the cerebral oximeter. The INVOS cerebral oximeter, which monitors rSO_2 changes in the capillary bed of the frontal cortex, is immediately alerted by critical changes in regional brain oxygenation and provides an opportunity for early intervention. Consequently, since effects of maternal supplementary oxygen on the newborn have been demonstrated by cerebral oximeter monitor and supported by umbilical cord blood gas analysis and Apgar scores, the INVOS cerebral oximeter may be a helpful monitoring tool for detecting real-time rSO_2 changes during regional obstetric anesthesia practice.

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