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Maternal hemodynamic influence on uteroplacental oxygen distribution during cesarean section

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Summary

This study investigated maternal hemodynamic influence on uteroplacental oxygen distribution and neonatal outcome during cesarean section (CS). CS was performed on 80 parturients using two anaesthetic techniques: spinal anaesthesia (SA) and general balanced anaesthesia (GBA). Indications for CS were exclusively obstetric related. Monitored maternal parameters were: ECG, heart rate (HR), non-invasive blood pressure (NIBP), saturation (SaO_2). Gas parameters in umbilical artery, vein, and neonatal capillary blood were sampled. Vitality was assessed by the Apgar scoring, first breath-taking time and the first breastfeeding attempt. Hypotension was the most common finding after SA induction. GBA group presented changes such as QT inversion (12.5%), tachycardia (55%), and bradycardia (2.5%). SA group experienced higher rates of sinus tachycardia (45%) and ventricular dysrhythmias (2.5%). Neonatal oxygenation was significantly higher in SA group. Higher quality of early neonatal adaptation in the SA group confirms it as the technique with the least neonatal risk during CS.

Key words: Caesarean section; Early neonatal adaptation; Transplacental oxygenation.

Introduction

The increasing number of cesarean sections (CS) worldwide over recent years has given rise to a need for research into the influences of maternal central hemodynamic changes in anaesthesia on newborns. Neonatal outcomes following CS are directly influenced by maternal health and respiratory and hemodynamic stability during anaesthetic induction. Inadequate uterine blood flow may result in impaired fetal oxygen uptake [1]. Uterine blood flow is not autoregulated and is a major determinant of oxygen delivery across the placenta. Factors that may obstruct uteroplacental perfusion and reduce the oxygen supply of the neonate are: maternal hypo- or hypertension, ECG rhythm disturbances that might result in impaired fetal oxygen uptake, maternal hypoventilation, and reduced concentration of maternal arterial blood oxygen. Decreased maternal values of oxygen can also be a direct cause of fetal asphyxia. Uteroplacental perfusion is proportional to blood pressure and therefore reduction to below a certain threshold results in inadequate fetal oxygenation. Because of fetal reserve and the different compensatory mechanisms, healthy fetuses can tolerate a decrease of 40-50% oxygen delivery without any untoward effect [2]. Acute respiratory acidosis of neonates can be caused by an accumulation of CO_2 because of a decrease in either uterine or umbilical flow. Maternal hypocapnia (< 25 mmHg) will cause uterine and umbilical vessel vasoconstriction [3]. Mechanical hyper- ventilation will increase thoracic pressure and reduce venous return as well as cardiac output and thus reduce uteroplacental blood flow [4]. Maternal alkalosis will shift the oxygen-hemoglobin dissociation curve to the left, and thus will have difficulty to extract oxygen [5].

Materials and Methods

The study was approved by Ethics Committee of the Medical faculty of the University of Belgrade (250/I-5). The present investigation comprised 80 American Society of Anaesthesiologists (ASA) I pregnant women (28 years, range: 20-38) in the 37th to the 42nd week of pregnancy, who were randomly assigned to be treated using one of two techniques of anaesthesia during CS. The indications for CS were exclusively obstetric related indications. In the first group (40 women) the anaesthetic technique used was spinal anaesthesia (SA) and in the second group (40 women) general balanced anaesthesia (GBA) was used. All patients were visited on the morning of the surgery by the investigator and informed consent was obtained from all patients. The protocol for the assignment of anaesthetic technique was randomised using the STATA commercial statistical analysis program. The randomisation was performed immediately before the initiation of anaesthetic procedures during CS.

During the preoperative period, the authors continuously monitored maternal non-invasive blood pressure (NIBP), heart rate

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Table 1. — *Main values of maternal systolic and diastolic non-invasive blood pressure during the time between anaesthetic induction and extraction of the neonate.*

Non-invasive blood pressure	Anaesthetic technique	Number of patients (N)	Main value of blood Pressure (mm Hg)	Standard deviation (SD)	Significance (p)
Systolic	Spinal	40	109.45	14.757	0.001
	General	40	129.85	15.734	
Diastolic	Spinal	40	73.72	12.816	0.013
	General	40	80.55	11.038	

Table 2. — *Incidence of ECG disturbances in both groups in the period before neonatal extraction during cesarean section.*

	Anaesthetic Technique		
ECG	Spinal	General	Frequency
Sinus rhythm	21 (52.5%)	12 (30%)	33 (41.2%)
Tachycardia	18 (45%)	22 (55%)	40 (50%)
Presence of Q wave	0	5 (12.5%)	5 (6.2%)
Ventricular extrasystolic disrhythmia (VES)	1 (2.5%)	0	1 (1.3%)
Bradycardia	0	1 (2.5%)	1 (1.3%)

Table 3. — *Saturation values (SpO_2) in the umbilical artery and vein, neonatal capillary samples, and maternal artery soon after the extraction of the neonate.*

SpO_2	Anaesthetic technique	Mean value (%)	Standard deviation (SD)	Standard error (SE)	Significance (p)
Umbilical artery	Spinal	27.11	13.08	2.01	0.53
	General	25.61	7.61	1.20	
Umbilical vein	Spinal	54.44	14.67	2.26	0.39
	General	51.90	11.90	1.88	
Neonatal capillary	Spinal	71.27	12.08	1.86	0.02
	General	65.42	11.27	1.78	
Maternal artery	Spinal	98.99	1.66	1.06	0.06
	General	98.82	1.09	0.92	

(HR), five-lead ECG dynamics, and pulse oximetry. They analysed maternal arterial blood gas (ABG) samples during the extraction of the neonate. Umbilical artery, vein and neonatal capillary samples were taken after extraction and used for the measurement of partial pressure of oxygen (PaO_2), carbon-dioxide ($PaCO_2$) and pH values. Neonatal Apgar score variables were monitored at the first (Apgar 1) and fifth minute (Apgar 2) after the extraction of the newborn. The time of the first breath was recorded and the effectiveness of the first attempt to breastfeed was noted.

Preoperative administration of antacids, H2 receptor agonists, and metoclopramide was performed due to aspiration prophylaxis. GBA was induced using propofol (two mg/kg), succinylcholine (one mg/kg), and the maintenance of anaesthesia was performed using 0.6%–1% sevoflurane combined with a mixture of 50% nitrous oxide and oxygen. Opiates were not administered before the delivery of the neonate. Before SA patients were preloaded with 1,000 ml crystalloid and/or colloid (Ringer lactate or Hartmann's solution and/or Hydroxyethyl-starch). SA was performed in a sitting position using a 26-7 gauge Sprotte needle inserted preferably at L2-L3 or L3-L4 level. Patients received 2.4 (± 0.3) ml of spinal 0.5% bupivacaine with 10-20 mcg fentanyl. Nasal oxygen supply was maintained (3-5 l/min) during the whole operation. Hypotension was randomly prevented by using bolus doses of 5-10 mg ephedrine (in case of less than 80% BP baseline values), repeated in one to two minutes until BP returned to normal values.

After the estimation of the primary adaptation scores, every neonate from SA group was put to the mother's breast for the first breastfeeding attempt. The same procedure was accomplished to the GBA parturient after complete recovery from the GBA.

Differences in outcome measures between matched pairs were assessed using universal analysis. Chi-square tests or Fisher`s exact tests (for independent samples) were used to detect significant differences (p values) between the groups in terms of outcome variables. Continuous variables were compared using the non-parametric Mann-Whitney U test. A p-value of < 0.05 was considered to be significant.

Results

Two groups of pregnant women (n = 40) were recruited for elective CS under either SA (group 1) or GBA (group 2). In the period between completed induction of anaesthesia and neonatal extraction (7-18 min), the authors found significantly different values of maternal systolic artery pressure ($p = 0.001$) and diastolic artery pressure ($p = 0.01$) between the groups with increased incidence of hypotension in the SA group (Table 1). Hypotension was gradually treated with ephedrine bolus doses or by continuous infusion (6–30 mg) causing a rapid recovery in blood pressure values.

During the same period, HR values differed significantly between the two groups ($p = 0.001$) with a noticeable increase in frequency in group 2. Decrease in HR was also observed only in group 2, with an incidence of 2.5%. Ventricular extrasystolic dysrhythmia was observed in only one patient (2.5 %) in group 1. Mild Q-T wave inversion in the standard D3 lead was present in 12.5% of cases in group 2 (Table 2).

Umbilical artery and vein saturation (SaO_2) did not show any significant differences in values between the groups. Capillary neonatal blood saturation had a higher range of values (71.2%) in the SA group (Table 3).

PaO_2 values in the umbilical cord artery differed significantly between the two groups ($p = 0.001$). Umbilical vein PaO_2 oxygen was significantly higher in the SA group (5.65±1.67 kPa) ($p = 0.003$), as well as group results of neonate capillary blood PaO_2 ($p = 0.03$) (Figure 1). The only $PaCO_2$ parameter to differ significantly between the groups was umbilical vein blood ($p = 0.01$) (Table 4).

Neonatal blood pH did not differ significantly between the two groups. Mean capillary pH was 7.29 in the SA group, compared with 7.30 in the GBA group.

Apgar score differed significantly between groups. Apgar scores in the SA group were higher in the first (8.4) and the

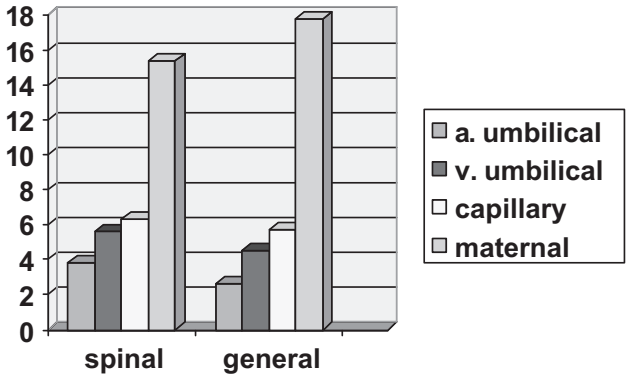

Figure 1. — Main values of PaO_2 in the umbilical artery and vein, neonatal capillary samples, and maternal artery in spinal and general anaesthesia groups after extraction of the neonate.

Table 4. — *$PaCO_2$ values in the umbilical artery and vein, neonatal capillary samples, and maternal artery soon after the extraction of the neonate.*

$PaCO_2$	Anaesthetic technique	Mean value (%)	Standard deviation (SD)	Standard error (SE)	Significance (p)
Umbilical artery	Spinal	6.55	1.105	0.17	0.137
	General	6.16	1.253	0.19	
Umbilical vein	Spinal	5.12	0.922	0.14	0.019
	General	5.63	0.993	0.15	
Neonatal capillary	Spinal	6.17	1.594	0.25	0.096
	General	6.72	1.318	0.20	
Maternal artery	Spinal	4.29	0.673	0.10	0.035
	General	3.97	0.674	0.10	

Table 5. — *Main values of Apgar score in the first (Apgar 1) and the fifth (Apgar 5) minute of neonatal adaptation.*

Apgar score	Anaesthetic technique	Mean values	Standard deviation (SD)	Median (M)	Standard error (SE)
Upgar 1	Spinal	8.435	0.787	9.00	0.126
	General	7.682	1.349	8.00	0.210
Apgar 5	Spinal	9.076	0.480	9.00	0.076
	General	8.585	0.921	9.00	0.143

fifth min (9.0) of neonatal adaptation compared with the GBA group (Table 5). Average neonatal first breath-taking time was shorter in the SA group (3 ± 2 s) compared with the GBA group (4 ± 3 s). After primary adaptation scores were estimated, each neonate in the SA group was put to its mother's breast for its first attempt at breastfeeding. The same procedure was done in the GBA group following complete recovery from anaesthesia. The release time of SA group newborns (three to five days) from the maternity ward was significantly shorter than the release time of GBA newborns (four to seven days) ($p < 0.05$).

Discussion

In light of the increasing number of CSs over recent years, the present study analysed the number of functional maternal influences that may disturb regular neonatal adaptation after extraction [6]. The most common haemodynamic findings were hypotension, compensatory tachycardia and, rarely, bradycardia [7]. The authors found statistically significant differences between the two groups in haemodynamic parameters during the period of induction of anaesthesia and soon after. Hartmann *et al.* [8] evaluated 3,315 pregnant women that underwent CS using SA and found hypotension in 30% of the cases. Carpenter *et al.* found a 33% incidence of hypotension during CS, defining hypotension as systolic values of less than 90 mmHg or 10% less than original blood pressure values [9-11]. Tarkikila and Isola [12] defined hypotension as a 30% decrease in pre-anaesthetic systolic pressure or its decrease to less than 85 mmHg. Maayan-Metzger *et al.* [13] found no negative effects of time-related delivery intervals on vital fetal parameters.

In the present study, increased heart rate soon after induction was present in 45% of cases in the SA group, and in 55% of cases in the GBA group. The authors also noticed a 2.5% decrease in maternal heart rate in the GBR group in the same period. Brenck *et al.* [14], in a study of 1,154 births, found a 12.7% rate of post-inductional bradycardia. Other studies have reported increases in heart rate from 0.3% [15] to 24% [16]. As a result of changes in autonomic control, pregnant women at term usually have heart rates of between 90 and 95 beats/min [17].

Maternal ECG analyses from the present study showed a 2.5% incidence of ventricular skipped beats and a 12.5% incidence of ischemic QT wave in the GBA group. Zhu *et al.* [18] confirmed the protective and nutritional effect of sevoflurane on the myocardium, its perfusion, and the metabolism of oxygen during GBA.

PaO_2 artery values of parturient were significantly higher in the SA group compared with those in the GBA group. In this group, umbilical artery PaO_2 was 3.85 ± 1.28 kPa compared with general group values of 2.68 ± 1.01 kPa. Umbilical vein main PaO_2 values in the SA group were 5.65 ± 1.67 kPa, compared with 4.59±1.40 kPa in the GBA group. Lindblad *et al.* [19] confirmed slower umbilical perfusion and hypooxygenation of the neonate in cases of spinal sympathycolysis. Ngan Kee *et al.* [20] reported their findings of PaO_2 values evaluating 60 neonates. Their values performing general anesthesia with 50% FiO_2 and sevoflurane 1 vol% were very close to the present results (umbilical vein PaO_2 4.7 kPa and umbilical artery blood PaO_2 2.9 kPa). Lawes *et al.* [21] found a main value of neonatal umbilical vein PaO_2 of 3.9 kPa. In the present study, the main value of umbilical artery $PaCO_2$ was 6.55 ± 1.10 kPa in the SA group, compared with 6.16 ± 1.25 kPa in the GBA

group ($p > 0.05$). Umbilical vein $PaCO_2$ in the SA group differed significantly to the of the GBA group, with values of 5.12 ± 0.92 kPa in the SA group and 5.63 ± 0.99 kPa in the GBA group. Westgate *et al.* [22], in their study of 1,942 neonates at delivery, presented results of $PaCO_2$ values in the umbilical vein of 5.4 kPa and of 7.1 kPa in the umbilical artery.

Mokarami *et al.* [23] in a study of 58 newborns immediately after extraction confirmed similar pH (7.305) and $PaCO_2$ values (7.30 kPa) and only significantly different lactate concentration between general and spinal group of ($p = 0.03$). Kotaska *et al.* [24] reported in the study of 189 neonates delivered by CS reference values of arterial cord blood: pH (7.05–7.39), pCO_2 (5.01–10.60 kPa), pO_2 (1.17–5.94 kPa) and venous cord blood: pH (7.10–7.42), pCO_2 (3.88–9.36 kPa), pO_2 (1.98–7.23 kPa), that are in the range of the present study's neonate blood gas values.

Conclusion

This study demonstrated that both the spinal and general anaesthetic techniques used in CS can cause a number of maternal haemodynamic disturbances and decreased perfusion in umbilical circulation. Considering the significantly higher values of transplacental oxygenation, capillary neonatal oxygen and increased quality of neonatal adaptation soon after extraction in the SA group, this technique should be considered the technique of first choice for CS.

References

[1] Datta S.: "Obstetric Anesthesia Handbook". 4th ed. New York: Springer, 2007.

[2] Wilkening R.B., Meschia G.: "Fetal oxygen uptake, oxygenation and acid-base balance as a function of uterine blood flow". *Am. J. Physiol.*, 1983, *24*, 749.

[3] Motoyama E.K., Rivard G., Acheson F., Cook C.D.: "Adverse effect of maternal hyperventilation on the foetus". *Lancet*, 1966, *1*, 286.

[4] Levison G., Shnider S.M., deLorimier A.A.: "Effects of maternal hyperventilation on uterine blood flow and fetal oxygenation and acid-base status". *Anesthesiology*, 1974, *40*, 340.

[5] Parer J.T., Eng M., Aoba H., Ueland K.: "Uterine blood flow and oxygen uptake during maternal hyperventilation in monkeys at cesarean section". *Anesthesiology*, 1970, *32*, 130.

[6] Jain L., Dudell G.G.: "Respiratory transition in infants delivered by Cesarean section". *Semin. Perinatol.*, 2006, *30*, 296.

[7] Magalhães E., Govêia C.S., de Araújo Ladeira L.C., Nascimento B.G., Kluthcouski S.M.: "Ephedrine versus phenylephrine: prevention of hypotension during spinal block for cesarean section and effects on the fetus". *Rev. Bras. Anestesiol.*, 2009, 59, 11. [Article in English, Portuguese].

[8] Hartmann B., Junger A., Klasen J., Benson M., Jost A., Banzhaf A., Hempelmann G.: "The incidence and risk factors for hypotension after spinal anaesthesia induction: An analysis with automated data collection". *Anaesthesia Analg.*, 2002, *94*, 1521.

[9] Carpenter R.L., Hogan Q.H., Liu S.S.: "Lumbosacral cerebrospinal fluid volume is the primary determinant of sensory block extent and duration during spinal anaesthesia". *Anesthesiology*, 1998, *89*, 24.

[10] Carpenter R.L., Caplan R.A., Brown D.L.: "Incidence and risk factors for side effects of spinal anaesthesia". *Anesthesiology*, 1992, *76*, 906.

[11] Teoh W.H.L., Sia A.T.H.: "Colloid preload versus coload for spinal anaesthesia for caesarean delivery: the effects on maternal cardiac output". *Anesth. Analg.*, 2009, *108*, 1592.

[12] Tarkkila P., Isola J.: "A regression model for identifying patients at high risk of hypotension, bradycardia and nausea during spinal anesthesia". *Acta Anaesthesiol. Scand.,* 1992, *36*, 554.

[13] Maayan-Metzger A., Schushan-Eisen I., Toris L., Etchin A., Kuint J.: "The effect of time intervals on outcome in elective Caesarean delivery at term under regional anaesthesia". *Int. J. Gynecol. Obstet.*, 2010, *11*, 224.

[14] Brenck F., Hartmann B., Jost A., Röhrig R., Obaid R., Brüggmann D., *et al.*: "Examining the influence of maternal bradycardia on neonatal outcome using automated data collection". *Int. J. Obstet. Anesth.*, 2007, *16*, 208.

[15] Geffin B., Shapiro L.: "Sinus bradycardia and asystole during spinal and epidural anaesthesia: a report of 13 cases". *J. Clin. Anesth.*, 1998, *10*, 278.

[16] Brizzi A., Greco F., Malvasi A., Valerio A., Martino V.: "Comparison of sequential combined spinal-epidural anesthesia and spinal anesthesia for cesarean section". *Minerva Anestesiol.*, 2005, *71*, 701.

[17] Ekholm E.M., Erkkola R.U., Piha S.J., Jalonen J.O., Metsala T.H., Antila K.J.: "Changes in autonomic cardiovascular control in mid pregnancy". *Clin. Physiol.*, 1992, *12*, 527.

[18] Zhu J., Jiang X., Shi E., Ma H., Wang J.: "Sevoflurane preconditioning reverses imparement of hippocampal long term potentiation induced by myocardial ischaemia-reperfusion injury". *EJA*, 2009, *26*, 961.

[19] Lindblad A., Marsal K., Bernow J.: "Fetal blood flow during intrathecal anaesthesia for elective caesarean section". *Br. J. Anaesth.*, 1988, *61*, 376.

[20] Ngan Kee W.D., Khaw K.S., Ma K.C., Wong A.S.Y., Lee B.B.: "Randomised, double blind comparison of different inspired oxygen fractions during general anaesthesia for Cesarean section". *r. J. Anaesth.*, 2002, *89*, 556.

[21] Lawes E.G., Newman B., Campbell M.J., Irwin M., Dolenska S., Thomas T.A.: "Maternal inspired oxygen concentration and neonatal status for Cesarean section under general anaesthesia". *r. J. Anaesth.*, 1988, *61*, 250.

[22] Westgate J.A., Garibaldi J.M., Green K.R.: "Umbillical cord blood gas analysis at delivery: A time for quality data". *r. J. Anaesth.*, 1994, *101*, 1054.

[23] Mokarami P., Wiberg N., Olofsson P.: "Hidden acidosis: an explanation of acid-base and lactate changes occurring in umbilical cord blood after delayed sampling". *BJOG*, 2013, *120*, 996. doi: 10.1111/1471-0528.12234. Epub 2013 Apr 10.

[24] Kotaska K., Urinovska R., Klapkova E., Prusa R., Rob L., Binder T.: "Re-evaluation of cord blood arterial and venous reference ranges for pH, pO_2, pCO_2, according to spontaneous or cesarean delivery". *JCLA*, 2010, *24*, 300.

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