Chapter 16
Effect of Spinal Anesthesia for Elective Cesarean Section on Cerebral Blood Oxygenation Changes: Comparison of Hyperbaric and Isobaric Bupivacaine

Yuko Kondo, Kaoru Sakatani, Noriya Hirose, Takeshi Maeda, Jitsu Kato, Setsuro Ogawa, and Yoichi Katayama

Abstract We used near-infrared spectroscopy (NIRS) to evaluate cerebral blood oxygenation changes in subjects undergoing cesarean section under spinal anesthesia (SP) with hyperbaric bupivacaine (group H, 27 subjects) or isobaric bupivacaine (group I, 15 subjects). In group H, total-Hb, oxy-Hb, and mean blood pressure (MBP) within 20 min after SP were significantly lower than the baseline values. In contrast, there was no significant change from baseline in total-Hb, oxy-Hb, or MBP in group I after SP. Total-Hb and MBP in group H were significantly lower than those in group I within 10 min after SP. There was no significant change of deoxy-Hb, tissue oxygen index, or heart rate from baseline in either of the groups. These results suggest that isobaric bupivacaine may be superior to hyperbaric bupivacaine for preventing a decrease of maternal cerebral blood flow after SP for cesarean section.

Keywords Cesarean • Bupivacaine

Y. Kondo (✉) • T. Maeda
Division of Neurosurgery, Department of Neurological Surgery,
Nihon University School of Medicine, 30-1, Oyaguchi-Kamicho, Itabashi-Ku,
Tokyo, 173-8610, Japan

Division of Anesthesiology, Department of Anesthesiology,
Nihon University School of Medicine, Tokyo, Japan
e-mail: yk-mikan@d8.dion.ne.jp

K. Sakatani
Division of Optical Brain Engineering, Department of Neurological Surgery,
Nihon University School of Medicine, Tokyo, Japan

N. Hirose • J. Kato • S. Ogawa
Division of Anesthesiology, Department of Anesthesiology,
Nihon University School of Medicine, Tokyo, Japan

Y. Katayama
Division of Neurosurgery, Department of Neurological Surgery,
Nihon University School of Medicine, 30-1, Oyaguchi-Kamicho, Itabashi-Ku,
Tokyo, 173-8610, Japan

W.J. Welch et al. (eds.), *Oxygen Transport to Tissue XXXIV*, Advances in Experimental Medicine and Biology 765, DOI 10.1007/978-1-4614-4989-8_16,

1 Introduction

Maternal hypotension is a common side effect after spinal anesthesia for cesarean section. Severe hypotension after spinal anesthesia may result in decreased cerebral blood flow and oxygenation, leading to maternal symptoms such as nausea, vomiting, and dizziness [1, 2]. Indeed, the relationship between hypotension and decrease in cerebral blood oxygenation (CBO) after spinal anesthesia has been evaluated by near-infrared spectroscopy (NIRS) [2], and it was found that isobaric bupivacaine has less influence on blood pressure than hyperbaric bupivacaine [3]. However, differences between the effects of hyperbaric and isobaric bupivacaine on cerebral blood flow and oxygenation have not been examined in detail. Therefore, we employed NIRS to evaluate CBO changes after spinal anesthesia with hyperbaric or isobaric bupivacaine for cesarean section.

2 Methods

We studied 47 ASA (American Society of Anesthesiologists) physical status I–II female patients (mean age 33.2 ± 5.7 years) scheduled for elective cesarean section under spinal anesthesia. Patient's profiles are shown in Table 16.1. Of the 47 patients, 32 received spinal anesthesia with hyperbaric bupivacaine (group H) and 15 with isobaric bupivacaine (group I). This study was approved by the Committee for Clinical Trials and Research on Humans of Nihon University School of Medicine, and each subject gave informed consent to participate.

2.1 Monitoring

The patients were monitored with automatic noninvasive blood pressure (NIBP) measurement on the right arm, pulse oximetry, and electrocardiography. We measured CBO changes in the forehead using NIRS (Niro pulse, Hamamatsu Photonics, Japan).

Table 16.1 Patients' characteristics and anesthetic data

	Group H ($n = 27$)	Group I ($n = 15$)
Age (years)	32.7 ± 5.7	34.4 ± 5.6
Height (cm)	158.3 ± 4.4	158.0 ± 6.1
Weight (kg)	61.2 ± 9.4	64.3 ± 12.1
Gestational age (weeks)	36–39	32–42
Dose of bupivacaine (mg)	11.5 ± 1.0	11.0 ± 0.5
Spinal block level at 20 min after spinal anesthesia (median range)	Th 3/3	Th 3/3
Incidence of hypotension (%)	24 (88.9)	3 (20)
Incidence of nausea and vomiting (%)	5 (18.5)	0 (0)
Total fluid (ml)	747.3 ± 135.9	762.4 ± 148.4

The NIR light from three laser diodes (775, 810, and 850 nm) is directed to the head through a fiber-optic bundle, and the reflected light is transmitted to a multisegment photodiode detector array. The NIRS system measures the concentrations of oxy-Hb, deoxy-Hb, total hemoglobin (total-Hb; oxy-Hb + deoxy-Hb), and the tissue oxygen index (TOI). We started measurements of CBO changes, mean arterial blood pressure (MBP), and heart rate (HR) before the anesthetic procedure and recorded these parameters every 1 min until 20 min after spinal anesthesia.

2.2 Anesthetic Procedure

Patients did not receive premedication. In the operating room, each patient was placed in the supine position and received 3 L/min of oxygen through a face mask and colloidal solution at a rate of 20 ml/kg/h. Three minutes later, baseline measurements (oxy-, deoxy-, total-Hb concentrations, TOI, MBP, and HR) were recorded. Then, the patient was placed in the lateral position to receive spinal and epidural anesthesia. An epidural catheter was inserted into L1/2 interspace and the lumbar puncture was performed at the L3/4 interspace. Conditions of anesthesia are summarized in Table 16.1. The patient was returned to the supine position immediately after spinal anesthesia. If hypotension (MBP <80% of baseline value or systolic blood pressure <90 mmHg) was observed, the patient was treated with ephedrine (i.v. bolus) and/or returned to left lateral uterine displacement.

2.3 Data Analysis

All results are expressed as mean ± SD or as median and range. MBP and CBO variables for each time interval were compared with the baseline values by analysis of variance (ANOVA) for repeated measurements. If the ANOVA revealed a significant interaction, post hoc analysis was performed using the Tukey–Kramer multiple comparison test when applicable. $P < 0.05$ was considered to represent a statistically significant difference.

3 Results

Data of five patients were excluded from this study due to technical problems during NIRS measurements. Hyperbaric bupivacaine was used in 27 patients (group H), and isobaric bupivacaine in 15 patients (group I). Patient's profiles and anesthesia data are shown in Table 16.1.

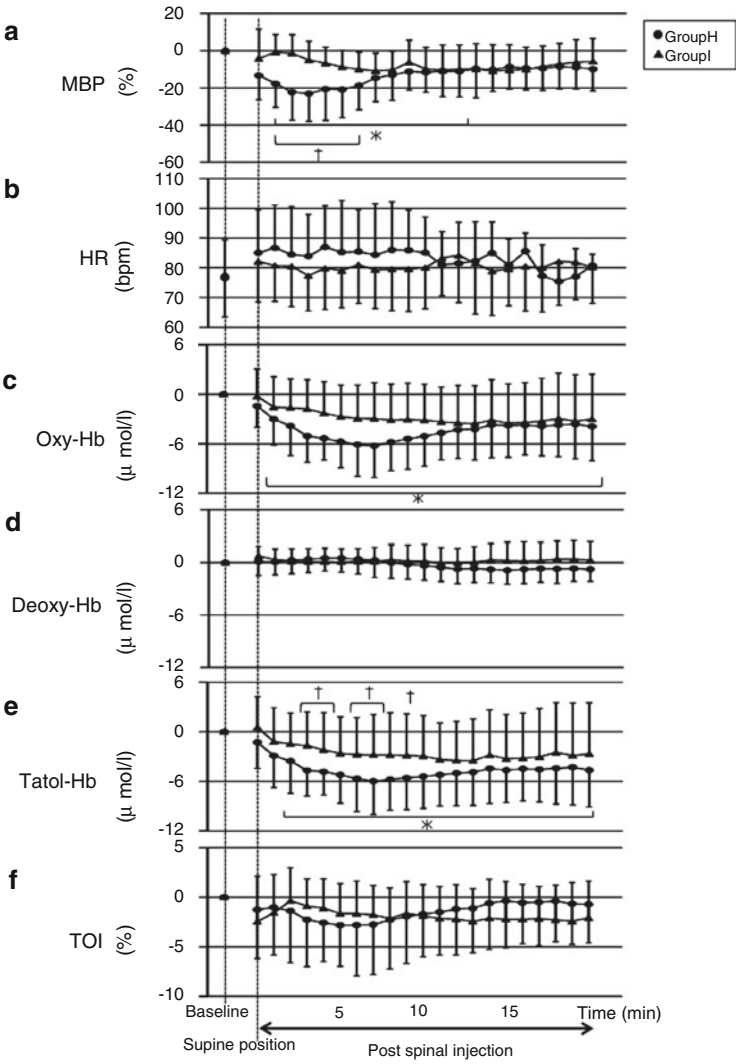

Fig. 16.1 MBP (**a**), HR (**b**), Oxy-Hb (**c**), Deoxy-Hb (**d**), Total-Hb (**e**), and TOI (**f**) versus time (data are mean ± SD). Changes in MBP, Hb concentrations, and TOI from baseline. *Oxy-Hb, total-Hb, and MBP were significantly decreased when compared with baseline values in group H ($P < 0.05$). †Total-Hb and MBP in group H were significantly lower than those in group I ($P < 0.05$)

Twenty-four patients (88.9%) in group H and three patients (20%) in group I suffered severe hypotension, which was symptomatic (nausea, vomiting, and dizziness) in five (18.5%) in group H; however, the three patients in group I exhibited no symptoms. Figure 16.1 compares mean changes of MBP, HR, oxy-Hb, deoxy-Hb, total-Hb concentrations, and TOI between group I and group H. In group H, oxy-Hb, total-Hb, and MBP within 20 min after spinal anesthesia were significantly

lower than the baseline values ($P < 0.05$), while HR, deoxy-Hb, and TOI did not change significantly. In contrast, there was no significant change in any parameter in group I. Total-Hb and MBP in group H were significantly lower than those in group I within 10 min after spinal anesthesia ($P < 0.05$).

4 Discussion

Our results show that spinal anesthesia with hyperbaric bupivacaine is associated with a decrease of oxy-Hb and total-Hb, which indicates a decrease of cerebral blood flow (CBF) and cerebral blood volume (CBV) [4, 5]. In contrast, spinal anesthesia with isobaric bupivacaine did not cause hypotension or CBO changes. These results suggest that maternal CBF may be decreased after spinal anesthesia with hyperbaric bupivacaine, but not with isobaric bupivacaine. These findings are consistent with a report indicating that hyperbaric bupivacaine caused hypotension and reduction of CBF [2]. Interestingly, hyperbaric bupivacaine did not change deoxy-Hb in the present study. This suggests that the reduction of CBF caused by hyperbaric bupivacaine might be moderate since changes of deoxy-Hb during ischemia are dependent on the degree of reduction of CBF [6]. It should be noted, however, that patients anesthetized with hyperbaric bupivacaine complained of symptoms such as nausea, suggesting that the reduction of CBF might have been sufficient to influence brain function. It is interesting that, although the degree of hypotension was within the functional range of cerebral autoregulation, spinal anesthesia with hyperbaric bupivacaine caused a reduction of CBF. It has been reported that an abrupt decrease of systemic blood pressure within the threshold of autoregulation can decrease CBF [7]. In addition, spinal anesthesia tends to rapidly decrease systemic blood pressure, for a period of several minutes [8]. These results suggest that the reduction of CBF under spinal anesthesia with hyperbaric bupivacaine was caused by a mild but rapid decrease in systemic blood pressure.

In general, hyperbaric bupivacaine tends to increase the anesthetic level more rapidly than isobaric bupivacaine and, therefore, hemodynamic changes are more severe with hyperbaric bupivacaine than with isobaric bupivacaine [3]. In addition, even a small dose of local anesthetic may induce hypotension, since the amount of cerebrospinal fluid decreases in the lumbosacral area in late pregnancy [9, 10]. These observations suggest that isobaric bupivacaine is more suitable for spinal anesthesia for cesarean section.

5 Conclusions

Measurements of CBO changes indicate that isobaric bupivacaine is more suitable than hyperbaric bupivacaine to prevent a reduction of CBF after spinal anesthesia for cesarean section.

Acknowledgments This research was partly supported by Japan Science and Technology Agency, under the Strategic Promotion of Innovative Research and Development Program, and a Grant-in-Aid from the Ministry of Education, Culture, Sports, Sciences and Technology of Japan (B23300247).

References

1. Datta S et al (1982) Method of ephedrine administration and nausea and hypotension during spinal anesthesia for cesarean section. Anesthesiology 56:68–70
2. Berlac PA, Rasmussen YH (2005) Per-operative cerebral near-infrared spectroscopy (NIRS) predicts maternal hypotension during elective caesarean delivery in spinal anesthesia. Int J Obstet Anesth 14:26–31
3. Gessel EF et al (1991) Comparison of hypobaric, hyperbaric, and isobaric solutions of bupivacaine during continuous spinal anesthesia. Anesth Analg 72:779–784
4. Ferrari M et al (1992) Effects of graded hypotension on cerebral blood flow, blood volume, and mean transit time in dogs. Am J Physiol 262:1908–1914
5. Pryds O et al (1990) Carbon dioxide-related changes in cerebral blood volume and cerebral blood flow in mechanically ventilated preterm neonates: comparison of near infrared spectrophotometry and 133 Xenon clearance. Pediatric Res 27:445–449
6. Baikoussis NG et al (2010) Baseline cerebral oximetry values in cardiac and vascular surgery patients: a prospective observational study. J Cardiothorac Surg 5:41
7. Zhang R et al (2002) Autonomic neural control of dynamic cerebral autoregulation in humans. Circulation 106:1814–1820
8. Langesaeter E et al (2008) Continuous invasive blood pressure and cardiac output monitoring during cesarean delivery. Anesthesiology 109:856–863
9. Higuchi H et al (2004) Influence of lumbosacral cerebrospinal fluid density, velocity, and volume on extent and duration of plain bupivacaine spinal anesthesia. Anesthesiology 100:106–114
10. Jawan B et al (1993) Spread of spinal anaesthesia for caesarean section in singleton and twin pregnancies. Br J Anaesth 70:639–641