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Original Article

Preoperative measurement of maternal abdominal circumference relates the initial sensory block level of spinal anesthesia for cesarean section: An observational study

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ABSTRACT

Objective: Lumbosacral cerebrospinal fluid volume is decreased as the enlarging uterus compresses the inferior vena cava during pregnancy. A subsequent greater cephalad spread of sensory blockade is observed. Gravid uterus plays a crucial role in affecting the spinal anesthesia level. We hypothesized that maternal abdominal circumference can reflect compressive effect of the uterus and investigated the relationship between abdominal circumference and the level of sensory blockade, and incidence of hypotension following spinal anesthesia with hyperbaric bupivacaine in term parturients.

Materials and Methods: Forty-two term parturients scheduled for elective cesarean section were studied. Abdominal circumference was measured before spinal anesthesia; 0.5% hyperbaric bupivacaine (2 mL, 2.2 mL, or 2.4 mL) was injected in to the subarachnoid space at the L3–L4 intervertebral level according to the parturient's height. The level of sensory blockade was assessed using an ice cube 1 minute, 5 minutes, 10 minutes, and 15 minutes after the spinal injection. The level of sensory blockade at the 15th minute was defined as the level of maximum sensory blockade. Statistical correlation coefficients were evaluated with Spearman's rank correlation.

Results: The correlation coefficient between the abdominal circumference and spinal level measured by cold sensation loss at 5 minutes after spinal anesthesia was significantly positive (right side $\rho = 0.43$, $p = 0.005$; left side $\rho = 0.46$, $p = 0.003$). No significant correlation was found between abdominal circumference and the level of maximum sensory blockade, the incidence of hypotension, ephedrine dosage, nausea, and vomiting after spinal anesthesia.

Conclusion: Parturients with greater abdominal circumference value have a higher level of sensory blockade at 5 minutes after spinal anesthesia. Abdominal circumference cannot predict the maximum sensory blockade level and the incidence of hypotension.

Introduction

Spinal anesthesia is widely used in parturients for cesarean section (C/S). Although it is considered a safe anesthetic method, nausea, vomiting, and hypotension are frequently reported after spinal anesthesia despite prehydration and left uterus displacement [1]. This is attributed to the greater aortocaval compression and greater cephalad spread of sensory blockade by an enlarged uterus [2,3]. Onuki et al [4] used magnetic resonance imaging and reported gestation-related reduction in cerebrospinal fluid (CSF) volume and dural sac surface area associated with the engorged veins in the epidural space [4]. Some studies also demonstrated a negative correlation between CSF volume and maximum sensory block level following spinal anesthesia with hyperbaric bupivacaine by magnetic resonance imaging in nonparturients [5,6]. Although a

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similar study has not been conducted in parturients, increased cephalad spread of local anesthetics has been reported in twin pregnancies compared with singleton pregnancies [7]. The speculated mechanism for this was that a larger gravid uterus caused greater engorgement of the epidural venous and resulted in a smaller CSF volume. Therefore, gravid uterus plays a crucial role in affecting the spinal anesthesia level for parturients.

Abdominal circumference (AC) correlates with intra-abdominal volume. Maternal AC increases during pregnancy, and it is influenced by fetus size, amniotic fluid, and uterus. These factors can have a compressive effect on the inferior vena cava (IVC) [8]. We hypothesized that maternal AC can reflect the degree of the compressive effect of an enlarged uterus, and we investigated the relationship between AC and the level of sensory blockade after spinal anesthesia. The secondary aims were to investigate the potential relationship between AC and the incidence of hypotension, nausea or vomiting, and the doses of ephedrine following spinal anesthesia with hyperbaric bupivacaine.

Materials and methods

After obtaining Mackay Memorial Hospital Institutional Review Board approval for this study, we obtained written informed consent from all participants. We prospectively enrolled 42 parturients with term pregnancy, with American Society of Anesthesiology physical status Class I or II, aged 20–40 years, and who were scheduled for elective C/S under spinal anesthesia. The exclusion criteria were obesity (body mass index > 30), multiple gestation, gestational diabetes mellitus, onset of labor, premature rupture of membrane, hemoglobin < 10 g/dL, any contraindication to neuraxial anesthesia, preeclampsia, pregnancy-induced hypertension, height of < 155 cm or > 170 cm, as well as history of spinal deformity or spinal surgery. All study participants were informed about the purpose of the study and the method used to measure the level of sensory blockade prior to anesthesia.

When the parturient arrived at the operating room, AC was measured by the same investigator while the patient was in the supine position. We measured the AC at the level of the umbilicus. These data were not revealed to the anesthetist, who was set to perform the spinal anesthesia later. Then standard monitors were installed, including an automated noninvasive blood pressure device, a pulse oximetry monitor, and an electrocardiography monitor. Baseline blood pressure and heart rate were recorded after an intravenous hydration of 1000 mL Lactated Ringer's solution over 15–20 minutes. After the hydration, we turned the parturient to the right lateral decubitus position on a horizontal operating table for spinal anesthesia. Spinal anesthesia was performed by the same anesthetist in all patients using the median approach through the L3–L4 intervertebral space. A Quincke 27-gauge spinal needle (Becton Dickinson S.A., Madrid, Spain) was inserted with its bevel oriented parallel to the dural fibers and then rotated 90° to direct the bevel cephalad. Then, 0.5% hyperbaric bupivacaine was injected into the subarachnoid space. No other adjunct was added. The dose of bupivacaine was determined by the parturient's height. Thus, 0.5% hyperbaric bupivacaine (2.0 mL) was administered when the height was between 156 cm and 160 cm; 0.5% hyperbaric bupivacaine (2.2 mL) was administered when the height was between 161 cm and 165 cm; and 0.5% hyperbaric bupivacaine (2.4 mL) was administered when the height was between 166 cm and 170 cm. A similar clinical management was found in other studies [9–11]. After the spinal injection, the patients were immediately returned to the supine position. A left uterine displacement of about 15° was maintained by inserting a folded blanket placed under the patient's right hip. No attempt was made to influence the level of sensory blockade by manipulating the operating table.

The blood pressure was measured at 1-minute intervals for 5 minutes and then at 2-minute intervals for 10 minutes after the spinal injection. Hypotension was defined as a drop in systolic blood pressure to below 100 mmHg, or a decrease of more than 30% in the baseline mean arterial blood pressure (MAP). Intravenous ephedrine (8 mg) was administered when hypotension was noted. Intravenous atropine (0.4 mg) was given when the heart rate was less than 60 beats/min. We checked the right and left side level of cold sensation loss by using an ice cube at 1 minute, 5 minutes, 10 minutes, and 15 minutes after spinal anesthesia. The level of sensory blockade at 15 minutes after spinal injection was defined as the level of maximum sensory blockade. Loss of cold sensation was assessed by asking the patient to report when the cold stimulus appeared similar to a reference point (forehead skin). The stimulus was advanced in a cranial direction on the foot until a sensation similar to the forehead skin was perceived. The dermatomal level below the detected stimulus was recorded as the level of sensory blockade. We also recorded the doses of ephedrine given and the incidence of nausea and vomiting during 15 minutes after spinal anesthesia.

Statistical analysis

Given that no previous study examined the correlation between block height and AC, we used CSF volume to estimate the sample size instead. The sample size determination was based on the correlation coefficient of −0.69 between CSF volume and peak sensory block level reported by Higuchi et al [5]. Given a two-tailed alpha level (α) of 5% and a power of 95% ($\beta = 5\%$), the minimum required sample size was 22. To consider the possibility of attrition data, 20% of the sample size was added, resulting in a total of 27 participants. In this study, we enrolled a total of 42 parturients to study the relationship between AC and the level of sensory blockade and hypotension after spinal anesthesia.

The clinical characteristics of the study participants are presented as means and standard deviation for continuous variables or number and percentage for categorical variables. Statistical correlation coefficients were evaluated with Spearman's rank correlation for the spinal anesthesia level, hypotension, and the doses of ephedrine, nausea or vomiting, and maternal AC. The spinal anesthesia level was measured at several time points (1 minute, 5 minutes, 10 minutes, and 15 minutes) and in both sides for which inflation of Type I error might emerge. Therefore, we used Bonferroni adjustment to set the statistical significance to a more strict level ($0.05/8 = 0.0063$) when conducting analyses of the spinal anesthesia level. All data analyses were performed using SPSS 15 (SPSS Inc., Chicago, IL, USA).

Results

Data were collected at Hsinchu Mackay Memorial Hospital from January 2014 to June 2014 at the operating room. A total of 42 parturients were enrolled in the study. Two of them were excluded because of spinal anesthesia failure and subsequently needed repeat spinal anesthesia. The demographic data of these 40 parturients are shown in Table 1. The mean AC was 98.4 ± 6.8 cm. The median level of sensory blockade by ice cube at 1 minute, 5 minutes, 10 minutes, and 15 minutes after spinal anesthesia are shown in Table 2. The correlation coefficients between the AC and the level of sensory blockade measured by using an ice cube were significantly positive at 5 minutes after spinal anesthesia (right side $\rho = 0.43$, $p = 0.005$; left side $\rho = 0.46$, $p = 0.003$; Table 3). The relationship is depicted in Figure 1. No correlation was found between AC and the level of maximum sensory blockade.

Table 1
Clinical characteristics of 40 parturient patients.

Variable	
Age (y)	32.9 ± 4.6
Height (cm)	161.5 ± 3.7
Weight (kg)	68.5 ± 7.3
Fetal gestational age (wk)	38.5 ± 0.6
Baby body weight (g)	3119.7 ± 275.0
Abdominal circumference (cm)	98.4 ± 6.8
Systolic blood pressure (mmHg)	122.9 ± 13.0
Diastolic blood pressure (mmHg)	75.4 ± 11.4
Mean arterial pressure (mmHg)	87.0 ± 11.8
Heart rate (beat/min)	84.8 ± 12.9
Ephedrine dose (mg)	24.2 ± 20.3
Nausea/vomiting (%)	20 (50.0)

Data are expressed as means ± SD for continuous variable or *n* (%) for categorical variable as appropriate.
SD = standard deviation.

Table 2
Median level of spinal sensory blockade by ice cube at 1 minute, 5 minutes, 10 minutes, and 15 minutes after spinal anesthesia.

Method (time)	Right side		Left side	
	Median	Range	Median	Range
Icy cold				
1 min	T10	S1–T4	T10	S1–T3
5 min	T5	T10–T1	T6	T12–T1
10 min	T3	T7–C8	T4	T8–C8
15 min	T2	T6–C7	T2	T7–C7

Data are expressed as median (interquartile range).

Table 3
Correlation between abdominal circumference and spinal anesthesia level for 40 parturient patients.

Method/time	Right side		Left side	
	ρ[a]	*p*	ρ[a]	*p*
Icy cold				
1 min	0.31	0.059	0.30	0.063
5 min	0.43	0.005*	0.46	0.003*
10 min	0.28	0.081	0.33	0.038
15 min	0.18	0.255	0.23	0.155

*Statistical significance, $p < 0.0063$ (Bonferroni adjustment).
[a] Spearman rank correlation.

Each parturient's blood pressure parameters were recorded at 1 minute, 2 minutes, 3 minutes, 4 minutes, 5 minutes, 7 minutes, 9 minutes, 11 minutes, 13 minutes, and 15 minutes after spinal anesthesia, resulting in a total of 10 records per patient. There were

Table 4
Correlation between abdominal circumference and hypotension, doses of ephedrine, and nausea/vomiting for 40 parturient patients.

Parameter	ρ[a]	*p*
Mean arterial pressure		
Amount of blood pressure decrease ≥ 30%	0.20	0.213
Blood pressure decrease ≥ 30% (yes/no)	0.15	0.355
Dose of ephedrine	0.03	0.866
Nausea/vomiting (yes/no)	0.05	0.750

[a] Spearman rank correlation.

25 (62.5%) patients who had decreased MAP of more than 30% compared to their baseline data prior to spinal anesthesia. The mean number of MAP decreased for the 10 visits was 2.0 ± 2.2. No significant correlation was found between AC and either presence/absence of blood pressure decrease or amount of blood pressure decrease for MAP (Table 4). There was no correlation between AC and either the doses of ephedrine or presence/absence of nausea and vomiting (Table 4).

Discussion

The purpose of this study is to investigate the relationship between maternal AC and the level of sensory blockade following spinal anesthesia. We demonstrated a significant correlation between AC and the level of sensory blockade at 5 minutes after spinal anesthesia. Parturients with greater AC value initially had a higher level of sensory blockade. This result supports our hypothesis that maternal AC can reflect the degree of the compressive effect of an enlarged gravid uterus on the IVC. Parturients with greater AC have less lumbosacral CSF volume owing to greater IVC compression and subsequent greater epidural venous plexus distension. This will cause a higher level of sensory blockade. However, the effect of the enlarged gravid uterus on CSF volume only influences the initial spinal anesthesia. We did not find any correlation between AC and the level of maximum sensory blockade. In addition, there was no correlation between AC and the incidence of hypotension, nausea or vomiting, and doses of ephedrine at 15 minutes after spinal anesthesia.

At 1 minute after spinal anesthesia, hyperbaric bupivacaine has just been injected into the subarachnoid space and its efficacy could not been fully observed at this moment. Then the efficacy of hyperbaric bupivacaine was enhanced by the enlarged uterus induced CSF volume decrease. We observed that parturients with greater AC values had a higher level of sensory blockade at the 5th minute. However, when the parturient lay supine, hyperbaric bupivacaine

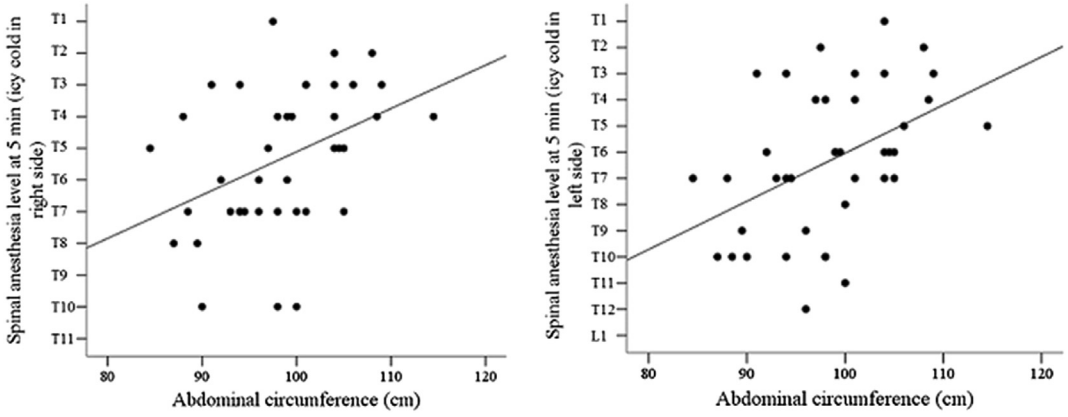

Figure 1. Relationship between abdominal circumference and spinal anesthesia level measured by ice at 5 minutes after spinal anesthesia. Correlation coefficient was 0.43 in the right side and $p = 0.005$. Correlation coefficient was 0.46 in the left side and $p = 0.003$.

only pooled in the lowest part of the thoracic curvature because the capacity of the upper thoracic pool could not be exceeded by the doses of hyperbaric bupivacaine used in this clinical trial [3]. De Simone et al [12] demonstrated that hyperbaric bupivacaine (15 mg) was needed to exceed this capacity and a higher level of sensory blockade could be achieved. This hindered the hyperbaric bupivacaine from acting at a higher spinal level in parturients with greater AC. We considered that this may explain why we could not find a correlation between AC and the level of maximum sensory blockade. Most of our parturients' maximum sensory blockade stayed at the thoracic level, but in five parturients sensory blockade was noted at the lower cervical level at 15 minutes after spinal anesthesia. Nevertheless, more extensive dermatomal spread was not found. Lee et al [13] investigated the relationship of AC and trunk length (TL) with spinal anesthesia level in the term parturient. In their study, 0.5% hyperbaric bupivacaine (2 mL) was injected at the L4–L5 intervertebral space in all parturients. They also failed to find any correlation between AC and maximum dermatomal level. In contrast to our study, they did not mention the level of sensory blockade at different time intervals.

Hypotension is a common side effect after spinal anesthesia in parturients. The incidence ranges from 50% to 80%. It develops in proportion to the extent of sympathetic blockade and sensory block height [1]. Our result showed that parturients with greater AC had a higher level of sensory blockade at 5 minutes after spinal anesthesia. Hence, we postulated that the magnitude of hemodynamic instability to spinal anesthesia would be severe in parturients with greater AC. However, our result did not show any correlation between AC and the incidence of hypotension. Hemodynamic response to spinal anesthesia is influenced by many factors such as hydration, venous capacitance, baseline peripheral vascular tone, blood volume, cardiac output, and the degree of aortocaval compression [1,14]. These factors can interact with each other and influence the blood pressure. Therefore, it is difficult to predict who is at risk of developing hypotension only by AC-related initial greater sympathetic block after spinal anesthesia. Jawan et al [7] investigated the spread of spinal anesthesia in parturients with singleton pregnancies and those with twin pregnancies. They noted that the mean AC of parturients with singleton pregnancies and those with twin pregnancies was 97.2 ± 5.7 cm and 105 ± 9.1 cm, respectively. Although increased cephalad spread of local anesthetics was found in twin pregnancies, the authors failed to find differences in the incidence of hypotension between the two groups.

Many factors can affect the level of sensory blockade in spinal anesthesia, including local anesthetics baricity, dose, volume, level of injection, needle type and alignment, patient age, height, weight, intra-abdominal pressure, and spinal anatomy [15,16]. However, the influence of most of these factors is small, unpredictable, and beyond the clinician's control [17]. The major factors are the baricity of the injected solution and the subsequent posture of the patient. We used the standardized anesthetic method to minimize these confounding factors' effect. Nevertheless, we performed spinal anesthesia in these parturients with different doses of hyperbaric bupivacaine according to their height. Although the volume and dose of bupivacaine was different and may be a confounding factor, it will not significantly alter the level of sensory block attained. Within the range of doses clinically used, different doses of hyperbaric bupivacaine will not produce a different level of sensory blockade because of the capacity of the thoracic spinal curvature [3,12]. Danelli et al [9] reported that a dose of 0.5% hyperbaric bupivacaine as low as 0.06 mg/cm height was needed to provide an adequately successful spinal block in nearly 95% of women undergoing elective C/S. Harten et al [10] also suggested adjusting the dose of hyperbaric bupivacaine according to parturient height and weight. The incidence of visceral pain during C/S was increased if the amount of 0.5% hyperbaric bupivacaine was not enough [18]. Therefore, we administered different doses of bupivacaine according to parturient height to avoid visceral pain during the operation.

Many parameters—including symphysis-fundal height, age, weight, height, body mass index or vertebral column length, and weight gain during pregnancy—have been studied to predict the level of sensory blockade during the spinal anesthesia for C/S [11,16,19]. However, all failed to show any correlation with the maximum sensory block level following spinal anesthesia for C/S. Based on the findings, CSF volume is a major determinant of the intrathecal spread of local anesthetics [5,6]. Arzola et al [20] studied the correlation between the diameter of the anterior and posterior lumbar dural sac, as assessed by ultrasound imaging, with spinal anesthesia sensory block level in parturients undergoing C/S. They did not find any correlation and considered that their simplified single measurement at one intervertebral space could not represent an accurate CSF volume. As aforementioned, Lee et al [13] studied the relationship of AC and TL with spinal anesthesia level, and found that the combination of AC and TL, the TL/AC^2, had some correlation with the level of spinal anesthesia. They considered that the body shape metrics and their influence on the anatomy of the spinal canal should be viewed in three dimensions. At present, most investigators have not found a parameter that can predict the maximum sensory block level in the parturient.

In conclusion, our study showed that parturients with greater AC value tend to have a higher level of sensory blockade at 5 minutes after spinal anesthesia. AC provides us a simple way to predict the initial effect of spinal anesthesia. The level of maximum sensory blockade is influenced by the baricity of bupivacaine, and no correlation was found. Further research is warranted to determine the role of isobaric bupivacaine in the relationship between spinal anesthesia level and parturient AC.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

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