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Abdominal girth and vertebral column length aid in predicting intrathecal hyperbaric bupivacaine dose for elective cesarean section

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Abstract

Currently, there is no consensus on how to determine the optimal dose of intrathecal bupivacaine for an individual undergoing an elective cesarean section. In this study, we developed a regression equation between intrathecal 0.5% hyperbaric bupivacaine volume and abdominal girth and vertebral column length, to determine a suitable block level (T5) for elective cesarean section patients.

In phase I, we analyzed 374 parturients undergoing an elective cesarean section that received a suitable dose of intrathecal 0.5% hyperbaric bupivacaine after a combined spinal-epidural (CSE) was performed at the L3/4 interspace. Parturients with T5 blockade to pinprick were selected for establishing the regression equation between 0.5% hyperbaric bupivacaine volume and vertebral column length and abdominal girth. Six parturient and neonatal variables, intrathecal 0.5% hyperbaric bupivacaine volume, and spinal anesthesia spread were recorded. Bivariate line correlation analyses, multiple line regression analyses, and 2-tailed *t* tests or chi-square test were performed, as appropriate. In phase II, another 200 parturients with CSE for elective cesarean section were enrolled to verify the accuracy of the regression equation.

In phase I, a total of 143 parturients were selected to establish the following regression equation: $Y_{T5} = 0.074X_1 - 0.022X_2 - 0.017$ (Y_{T5} = 0.5% hyperbaric bupivacaine volume for T5 block level; X_1 = vertebral column length; and X_2 = abdominal girth). In phase II, a total of 189 participants were enrolled in the study to verify the accuracy of the regression equation, and 155 parturients with T5 blockade were deemed eligible, which accounted for 82.01% of all participants.

This study evaluated parturients with T5 blockade to pinprick after a CSE for elective cesarean section to establish a regression equation between parturient vertebral column length and abdominal girth and 0.5% hyperbaric intrathecal bupivacaine volume. This equation can accurately predict the suitable intrathecal hyperbaric bupivacaine dose for elective cesarean section.

Abbreviations: AC = abdominal circumference, ASA = American Society of Anesthesiologists, C = cervical vertebra, IV = intravenous, L = lumbar vertebra, SH = sacral hiatus, T = thoracic vertebra, TL = trunk length.

Keywords: cesarean section, determinants of spinal level, local anesthetics

1. Introduction

Spinal anesthesia using hyperbaric bupivacaine is the preferred anesthetic technique for elective cesarean section.[1] To date, the technique has remained very popular in term parturients.[2,3] However, it is a challenge for the anesthetist to achieve a suitable spinal spread for cesarean section because of individual variations among parturients.[4] Excessively high cephalad spread after spinal anesthesia could result in hypotension, which is a common event in the term parturient,[5] leading to maternal nausea, vomiting, dizziness, and potential fetal effects. On the other hand, insufficient spinal spread may cause pain and other discomfort in patients.

Previous studies have explored the factors that affect the cephalad spread of spinal anesthesia.[1,2,6–16] The parturient characteristics that are typically considered when determining the dosage of local anesthetics for cesarean section include height,[17] weight,[17–19] body mass index,[2] vertebral column length,[6,15] abdominal circumference (AC),[15] and twin pregnancies.[8] Despite these studies, it remains a challenge to calculate the optimal intrathecal bupivacaine dose for cesarean section.

Our previous study demonstrated that abdominal girth and vertebral column length have high predictive values for the spinal spread in the term parturient.[20] However, the results did not provide a specific intrathecal hyperbaric bupivacaine dose for an individual parturient. A previous study suggested that T5 blockade to pinprick might be a suitable marker for determining intrathecal hyperbaric bupivacaine efficacy before cesarean section.[21] Therefore, in this prospective, observational study, we aimed to determine the specific regression equation between abdominal girth and vertebral column length and intrathecal

Editor: Somchai Amornyotin.

C-nW and Q-hZ have contributed equally to the manuscript.

This work was supported by Technology Bureau of Jiaxing, Zhejiang Province (2015C23023) and Health Development Planning Commission of Zhejiang Province (2015KYB389).

The authors report no conflicts of interest.

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Medicine (2017) 96:34(e7905)

Received: 27 June 2017 / Received in final form: 28 July 2017 / Accepted: 31 July 2017

http://dx.doi.org/10.1097/MD.0000000000007905

0.5% hyperbaric bupivacaine volume for T5 blockade to pinprick during elective cesarean section, and verify the accuracy of the regression equation.

2. Materials and methods

2.1. Patients and study design

Approval for the study was obtained from the Ethical Committee of Jiaxing Maternity and Child Health Care Hospital in July 2014 (CZJM201425), and informed consent was obtained from all participants.

In phase I of this prospective investigation, 416 term parturients who presented for elective cesarean section under spinal anesthesia from January to September 2016 were enrolled to investigate the regression equation between term parturients' variables and intrathecal hyperbaric bupivacaine dose for T5 blockade level to pinprick. Inclusion criteria were as follows: American Society of Anesthesiologists (ASA) physical status I or II, age between 19 and 40 years, singleton pregnancy, and gestational age over 37 weeks. Exclusion criteria were as follows: history of allergy to bupivacaine, contraindication for spinal anesthesia, spinal puncture failure, or significant medical or obstetric morbidity (ie, higher than the inclusion criteria of ASA physical status II). An additional 200 term parturients were enrolled to verify the accuracy of the regression equation from October to February 2016, which was regarded as phase II. The inclusion criteria and exclusion criteria were the same as in phase I.

Prior to the surgical procedure, the parturient fasted approximately 8 hours. Upon arrival to the operation room, standard ASA monitoring was performed, intravenous (IV) access was established, and 7 mL/kg Ringer lactate solution was preloaded before administering the anesthesia. After the parturient was placed supinely on the horizontal operating table, abdominal girth was measured at the level of the umbilicus at the end of expiration, and vertebral column length was measured from the C7 vertebra to the sacral hiatus (C7-SH). A CSE was performed at the L3/4 interspace in the right lateral decubitus with a midline approach, and a loss of resistance technique with about 0.5 mL of 0.9% saline was used for the epidural puncture. Before puncture, the L3/4 interspace was confirmed by ultrasonic imaging. The spinal component was performed with a needle-in-needle technique using a 26-gauge pencil-point needle. T5 spinal block level (between the nipple plane and the rib arch plane) was set as the target level, and a suitable dose of room temperature 0.5% hyperbaric bupivacaine with no opioids, which evaluated by the anesthesiologist, was injected intrathecally at a speed of approximately 2 mL in 10 seconds when free flow of the cerebrospinal fluid was obtained. An epidural catheter was inserted approximately 3 cm into the epidural space cephalad with no drug administered. After these procedures, the parturient was rapidly placed in a supine position, with a right pelvic wedge placed to facilitate left uterine displacement. Patients were not allowed to be placed in the Trendelenburg or other position within 15 minutes after intrathecal injection. The cephalad spread of spinal anesthesia was assessed in both midclavicular lines for the loss of pinprick discrimination at 3-minute intervals after intrathecal injection. After 15 minutes, the patient was evaluated to determine whether the spinal anesthesia produced a loss of pinprick discrimination in both midclavicular lines at T5 after the intrathecal injection. Patients that met this requirement were selected for establishing the regression equation between term parturients' variables and intrathecal hyperbaric bupivacaine dose. If the T5 sensory of pinprick discrimination was not obtained within 15 minutes after local anesthetic administration, 5 mL of 2% lidocaine was administered with a bolus injection through the epidural catheter for rescue analgesia as needed, and repeated as required. The surgery was started 15 minutes after intrathecal injection in the patients with sufficient spinal spread.

Phase I of the study was concluded when the sample size was large enough and the regression equation between term parturients' variables and intrathecal hyperbaric bupivacaine dose for T5 blockade level to pinprick was obtained. Subsequently, phase II of the study was initiated by enrolling an additional 200 parturients to verify the accuracy of the regression equation. The anesthesia method was the same as previously described, and the intrathecal hyperbaric bupivacaine dose was calculated by the regression equation obtained in phase I.

All anesthesia procedures were performed by the same attending anesthesiologist, and the assessment of cephalad spread of spinal anesthesia was completed by another anesthesiologist who was blind to the parturients' measurements. Hypotension was defined as a decrease in systolic pressure greater than 30% or systolic pressure values less than 90 mm Hg, and was treated with 50 μg of phenylephrine intravenously. Bradycardia was defined as heart rate values less than 55 beats/min, and was treated with 0.5 mg of atropine intravenously. If hypotension in association with bradycardia occurred, 10 mg of ephedrine was administered, and the vasoactive agent was repeated as needed. Oxygen (5 L/min) was administered to all parturients through a facial mask from the beginning of spinal anesthesia. If the parturient felt dyspneic, respiratory support was provided.

All parturient demographic variables were recorded, including age, height, weight (on the day of surgery), and the duration of surgery. In addition, all fetal demographic variables were recorded, such as neonatal weight, Apgar scores (1, 5, and 10 minutes after delivery), and fetal biparietal diameter. The spinal anesthesia level of loss of pinprick discrimination, 0.5% hyperbaric bupivacaine volume, and time for block to recede to T10 were also recorded.

2.2. Statistical analysis

In this study, 6 parturient's variables were evaluated, including age, weight, height, fetal biparietal diameter, vertebral column length, and abdominal girth. Sample size was calculated by G*Power 3.1.9.2, and a minimum sample size of 123 was needed to detect a desired statistical power level of 0.9, at a probability level of .05, with an anticipated effect size of 0.15 for the regression equation.

Data are presented as mean ± standard deviation, median (range), and n (%). IBM SPSS Statistics for Windows 19.0 (IBM Corp, Armonk, NY) was used for data analysis. Bivariate linear correlation analysis was applied to determine the relationship between parturient's age, weight, height, vertebral column length, abdominal girth, and fetal biparietal diameter, and intrathecal hyperbaric bupivacaine dose for T5 block level. Among these 6 predictors, multiple regression analysis with the stepwise method was performed to identify the dominating predictors for the intrathecal hyperbaric bupivacaine dose reaching T5 sensory level of pinprick discrimination. Quantitative data were analyzed using 2-tailed *t* tests. The categorical variables were analyzed using the chi-square test or exact probability. R^2 is the coefficient of determination, which indicates

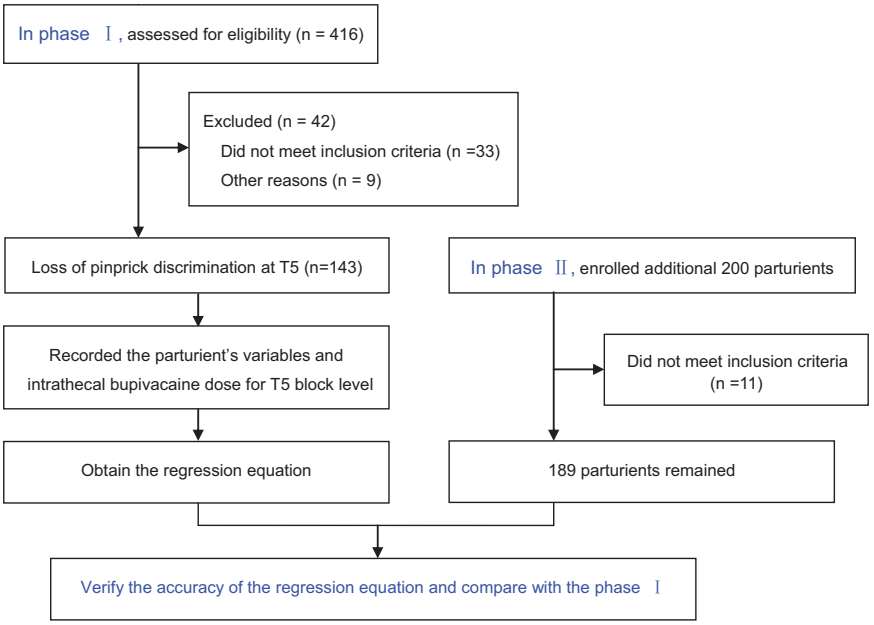

Figure 1. CONSORT flowchart for abdominal girth and vertebral column length can estimate intrathecal hyperbaric bupivacaine dose for elective cesarean section.

the proportion of the variance in the dependent variable that is predictable from the independent variable(s). A P value $<.05$ was regarded as statistically significant.

3. Results

In phase I of the study, 416 patients were initially considered for evaluation, but only 372 met the inclusion criteria required for enrolment, including 143 parturients with loss of pinprick discrimination at T5 (Fig. 1). The variables of the parturients and neonates used to obtain the regression equation are summarized in Table 1. The linear correlation analysis obtained from these variables indicated that there was a significant univariate correlation between a parturient's height, weight, abdominal girth, or vertebral column length, and the volume of 0.5% hyperbaric bupivacaine for T5 block level ($P<.01$ or $P<.001$) (Table 2; Figs. 2 and 3).

Subsequently, a multiple linear regression analysis was used to model the relationship between the parturient's variables and the volume of 0.5% hyperbaric bupivacaine for T5 block level. The results showed that a parturient's abdominal girth and vertebral column length were the key determinants of spinal spread (both $P<.001$). In contrast, a parturient's age, height, weight, or fetal biparietal diameter had no significant correlation with spinal spread (all $P>.29$) (Table 3). The regression equation between the 0.5% hyperbaric bupivacaine volume and vertebral column length and abdominal girth for loss of pinprick discrimination at T5, was $Y_{T5}=0.074X_1-0.022X_2-0.017$ (Y = 0.5% hyperbaric bupivacaine volume; X_1 = vertebral column length; and X_2 = abdominal girth). Importantly, the adjusted R^2 was 0.907, indicating that the equation had a predicted accuracy of 90.7%.

In phase II of the study, an additional 200 patients were considered for inclusion into the study to verify the accuracy of the regression equation, and 189 participants were enrolled after 11 parturients failed to meet the inclusion criteria (Fig. 1). The variables of the parturients and neonates are summarized in Table 4. No difference was found in the parturient and neonatal demographic variables between phase I and phase II ($P>.05$) (Table 4). The number of the parturients with the block level of

Table 1

Parturient and neonatal demographic variables for obtaining the regression equation.

The demographic variables of parturient, fetus, and neonate (n = 143)	
ASA status (I/II)	116/27
Age, y (mean ± SD)	30.7 ± 4.2
Height, cm (mean ± SD)	158.6 ± 4.5
Weight, kg (mean ± SD)	68.7 ± 9.1
BMI, kg/m^2 (mean ± SD)	26.9 ± 3.3
Abdominal girth, cm (mean ± SD)	99.1 ± 7.1
Vertebral column length (C7-SH), cm (mean ± SD)	55.5 ± 3.3
The volume of 0.5% hyperbaric bupivacaine, mL (mean ± SD)	1.9 ± 0.3
Fetal biparietal diameter, cm (mean ± SD)	90.3 ± 4.8
Neonatal weight, kg (mean ± SD)	3.2 ± 0.6
Neonatal Apgar scores (1 min after delivery) (media [range])	10 (5, 10)

ASA = American Society of Anesthesiologists, BMI = body mass index, C7-SH = the distance from sacral hiatus to C7 vertebra, SD = standard deviation.

Table 2

The relationship among parturient, fetus variables, and the volume of 0.5% hyperbaric bupivacaine for T5 block level (n = 143).

Parturient or neonatal variables	The volume of 0.5% hyperbaric bupivacaine for T5				
	r	95% CI		*P* value	*b*
Age	0.096	−0.067	0.255	.25	0.007
Height	0.517	0.359	0.642	<.001	0.033
Weight	−0.266	−0.405	−0.124	<.01	−0.009
Fetal biparietal diameter	−0.041	−0.235	0.154	.62	−0.003
Abdominal girth	−0.501	−0.363	−0.501	<.001	−0.021
Vertebral column length (C7-SH)	0.803	0.725	0.866	<.001	0.073

b = Regression coefficient, C7-SH = the distance from sacral hiatus to C7 vertebra, 95% CI = 95% confidence interval of correlation coefficients, r = correlation coefficient.

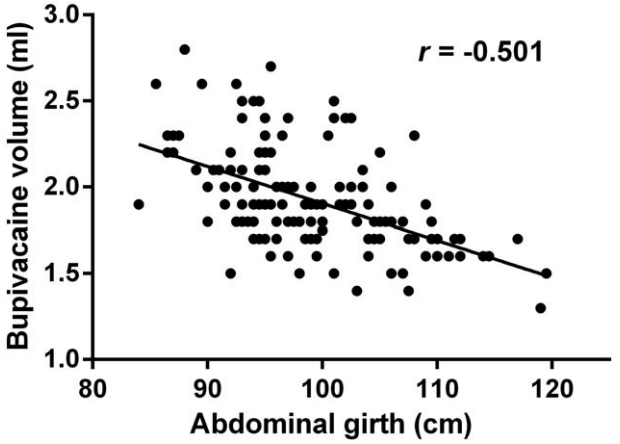

Figure 2. Bivariate linear correlation analysis of abdominal girth and intrathecal 0.5% hyperbaric bupivacaine dose for T5 block level in the term parturient ($r = -0.501$, $P < .001$). r = correlation coefficient.

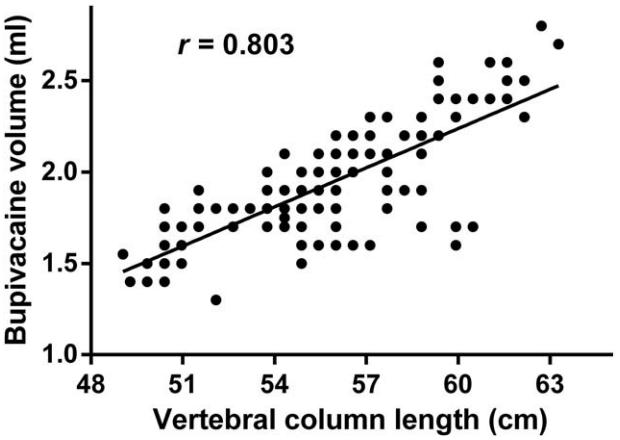

Figure 3. Bivariate linear correlation analysis of vertebral column length and intrathecal 0.5% hyperbaric bupivacaine dose for T5 block level in the term parturient ($r = 0.803$, $P < .001$). r = correlation coefficient.

T5 was 143 and 155, which accounted for 38.23% and 82.01% of all participants in phase I and II, respectively ($P < .001$). Rescue analgesia required in phase I was significantly higher than that in phase II (13.64% vs 4.76%, $P < .001$). Similarly, the use of a vasoactive agent was also significantly higher in phase I than in phase II (45.19% vs 28.57%, $P < .001$). Moreover, the time for the block to recede to T10 in parturient with nonrescue analgesia was 116 ± 17 and 102 ± 21 minutes in phase I and II, respectively. In addition, the average volume of 0.5% hyperbaric bupivacaine used in phase I was significantly larger than that used in phase II (2.1 ± 0.4 mL vs 1.9 ± 0.3 mL, $P < .001$). It is also worth noting that in phase II the highest block level was T3, and the lowest block level was T7 (Table 5).

Table 3

The multiple linear regression of parturient and fetus variables to spinal spread for pinprick discrimination (n = 143).

Parturient or fetus variables	Loss of pinprick discrimination			
	B	95% CI		*P* value
Age	0.027	—	—	.29
Height	0.004	—	—	.99
Weight	−0.031	—	—	.57
Fetal biparietal diameter	−0.006	—	—	.82
Abdominal girth	−0.022	−0.024	−0.020	<.001
Vertebral column length (C7-SH)	0.074	0.070	0.079	<.001

b = regression coefficient, C7-SH = the distance from sacral hiatus to C7 vertebra, 95% CI = 95% confidence interval of partial correlation coefficients.

Table 4

The parturient and neonatal demographic variables in phase I and II.

The demographic variables of parturient, fetus, and neonate	Phase I (n = 374)	Phase II (n = 189)
ASA status (I/II)	307/67	151/38
Age, y (mean ± SD)	30.8 ± 3.8	30.3 ± 4.1
Height, cm (mean ± SD)	158.8 ± 4.7	159.0 ± 4.9
Weight, kg (mean ± SD)	67.2 ± 9.6	68.8 ± 9.9
BMI, kg/m^2 (mean ± SD)	27.5 ± 3.1	27.2 ± 3.4
Abdominal girth, cm (mean ± SD)	99.5 ± 6.6	99.3 ± 7.0
Vertebral column length (C7-SH), cm (mean ± SD)	55.9 ± 3.2	55.6 ± 3.4
Fetal biparietal diameter, cm (mean ± SD)	8.96 ± 0.48	9.05 ± 0.51
Neonatal weight, kg (mean ± SD)	3.2 ± 0.5	3.2 ± 0.6
Neonatal Apgar scores (1 min after delivery) (media [range])	10 (6, 10)	10 (6, 10)
Duration of surgery, min (mean ± SD)	43.8 ± 9.8	43.3 ± 10.2

ASA = American Society of Anesthesiologists, BMI = body mass index, C7-SH = the distance from sacral hiatus to C7 vertebra, SD = standard deviation.

4. Discussion

In a recent study, we demonstrated that spinal anesthesia spread after administration of 2 mL of 0.5% hyperbaric bupivacaine intrathecally can be predicted by a parturients' abdominal girth and vertebral column length.[20] In the present study, we expanded upon this finding by calculating a regression equation

Table 5

The information of spinal block level distribution in phase I and II.

The information of hyperbaric bupivacaine dose and spinal block level distribution	Phase I (n = 374)	Phase II (n = 189)
The block level of spinal anesthesia was T5, n, %	143 (38.23%)	155 (82.01%)*
The block level of spinal anesthesia above T5, n, %	157 (42.2%)	19 (10.05%)*
The block level of spinal anesthesia below T5, n, %	74 (19.79%)	15 (7.94%)*
The upmost cephalad spread	C7	T3
The lowest cephalad spread	T9	T7
One spinal segment deviation, n, %	138 (36.90%)	30 (15.87%)*
Two spinal segments deviation, n, %	52 (13.90%)	4 (2.12%)*
Three and more than 3 vertebral column segments deviation, n, %	41 (10.96%)	0*
The number of rescue analgesia, n, %	51 (13.64%)	9 (4.76%)*
The volume of 0.5% hyperbaric bupivacaine, mL (mean ± SD)	2.1 ± 0.4	1.9 ± 0.3*
The use of vasoactive agent, n, %	169 (45.19%)	54 (28.57%)*
Phenylephrine, n	135	41
Atropine, n	13	4
Ephedrine, n	21	9

Compared with Phase I. SD = standard deviation.
* $P < .001$.

between the parturient vertebral column length and abdominal girth and the 0.5% hyperbaric intrathecal bupivacaine volume for loss of pinprick discrimination at T5, and obtained an adjusted R^2 of 0.907. Taken together, our results indicate that an accurate intrathecal hyperbaric bupivacaine dose for an individual undergoing cesarean section can be obtained from the parturient's abdominal girth and vertebral column length. In agreement, parturients with minor abdominal girth and longer vertebral column length often need a larger dose of intrathecal hyperbaric bupivacaine for cesarean section.

Multiple investigations have previously attempted to address the problem of calculating the appropriate intrathecal bupivacaine dose for cesarean delivery.[18,22,23] However, these investigations only determined the effective bupivacaine doses for 50% to 95% of participants (ie, ED_{50} and ED_{95}), or determined the minimum effective dose. Consequently, these studies only provided a reference range for the bupivacaine dose, without addressing how to calculate a specific, individualized dose. Interestingly, Harten et al[17] proposed including the parturient's height and weight as important variables for adjusting the intrathecal bupivacaine dose for cesarean section, but the accuracy was disputed.[2,19,24] In the present study, we provided a reliable individualized hyperbaric bupivacaine dosing for the parturient during spinal anesthesia. Our results suggest that it is possible to calculate the appropriate bupivacaine dose for an individual after taking into consideration the parturient's abdominal girth and vertebral column length. Many previous investigations have attempted to resolve the problem of the suitable dosage of intrathecal bupivacaine for cesarean delivery[18,22,23] but all these investigations obtained the effective bupivacaine doses for only 50% to 95% of participants (ED_{50}, ED_{95}) or the minimum effective dose. The studies provided only a reference range of bupivacaine dosage, not individualized dosage. Harten et al[17] adopted the parturient's height and weight to adjust the intrathecal bupivacaine dose for cesarean section, but the accuracy was disputed.[2,19,24]

The determination coefficient (R^2) of the regression equation between intrathecal bupivacaine dose and the parturients' abdominal girth and vertebral column length was 0.907, which indicates the parturients' abdominal girth and vertebral column length can predict the hyperbaric bupivacaine dose for loss of T5 pinprick discrimination with an accuracy of 90.7%. This finding is significant for cesarean section. As analyzed in our previous investigation, the high degree of predictability is primarily because the parturient's abdominal girth and vertebral column length can reflect the volume of lumbosacral cerebrospinal fluid.[20] In agreement, a recent study showed that the trunk length/abdominal circumference[2] (TL/AC^2) is corrected with the maximal spinal spread level, which suggests that a parturient with a shorter TL and a larger AC tends to obtain a higher spinal level.[15] However, the equation from their study only yielded a R^2 equal to 0.2.

In phase II of the study we verified the regression equation by using an independent group of patients. Among 189 parturients, there were 155 parturients that attained a spinal block level of T5, and the maximum deviation was 2 spinal segments to either side. Importantly, the accuracy of the equation was significantly higher than simply relying on the experience of the anesthesiologist (82.01% vs 38.23%). Although the accuracy of the equation was lower than the theoretical value (90.7%), the results are nonetheless encouraging. It should be noted that in clinic, many factors may affect the accuracy of the regression equation.

The measurement of intrathecal drug distribution is difficult. Thus, indirect indicators, such as touch, pinprick, or cold, have been adopted in previous studies.[25] For example, it has been proposed that a bilateral T5 to pinprick discrimination as the target spinal spread level might be a suitable level for cesarean section.[21] Alternatively, a separate study regarded T6 as the suitable spinal spread level.[18] However, in clinical practice large variations exist, and many parturients are comfortable and satisfied with their anesthesia despite having a block to pinprick discrimination below T6. Consequently, to meet the needs of a large proportion of the parturients, a bilateral T5 to pinprick discrimination was set as the target spinal spread level in this study. It is likely that some parturients will find a particular modality, such as cold discrimination, easier to discern than pinprick. Therefore, multiple indicators used for the assessment at the same time would gain more accuracy. In the present study, only the pinprick method was used, and it was a limitation of this study.

A previous study demonstrated that CSE anesthesia could provide a higher block level for the parturient than an equivalent single-shot spinal anesthesia.[26] Therefore, in our present study we based the establishment of the regression equation off of treatment with CSE, without considering single-shot spinal anesthesia. Consequently, the intrathecal bupivacaine dose obtained from the regression equation may be relatively insufficient for single-shot spinal anesthesia, which is one of the limitations of the study. The possible reason for differences between dose requirements of CSE and single shot might be that the negative pressure disappears after epidural puncture, and the dural sac becomes extruded, causing a decrease in lumbosacral cerebrospinal fluid volume, which would lead to higher cephalad spread of spinal anesthesia. In the clinic, the epidural component of the procedure may also alter the spinal spread. For example, the volume of saline used for the loss-of-resistance epidural technique, and the time required to feed the epidural catheter before moving the patient supine, may inadvertently affect the spinal spread.

Additional limitations of the study include that this was a single center study, and it is unclear as to whether this formula would translate to different ethnic groups. In addition, the body habitus is not representative of many geographical areas mean weight 68.7kg. Finally, in this study, we only investigated the dose required to achieve a block to T5 as a surrogate for adequate anesthesia for cesarean section. However, it is also important to investigate the factors that influence the duration of adequate surgical blockade.

In conclusion, in this study we were able to obtain the regression equation between the parturient vertebral column length and abdominal girth, and the 0.5% hyperbaric intrathecal bupivacaine volume for loss of pinprick discrimination at T5 according to the following equation: $Y_{T5} = 0.074X_1 - 0.022X_2 - 0.017$ ($Y = 0.5\%$ hyperbaric bupivacaine volume; X_1 = vertebral column length; and X_2 = abdominal girth). The regression equation can accurately predict the suitable intrathecal hyperbaric bupivacaine dose for elective cesarean section.

Acknowledgments

We thank Qi-Li for copyediting.

References

[1] Morgan P. Spinal anaesthesia in obstetrics. Can J Anaesth 1995;42: 1145–63.
[2] Ngaka TC, Coetzee JF, Dyer RA. The influence of body mass index on sensorimotor block and vasopressor requirement during spinal anesthesia for elective cesarean delivery. Anesth Analg 2016;123:1527–34.

[3] Ngan Kee WD, Lee SW, Ng FF, et al. Randomized double-blinded comparison of norepinephrine and phenylephrine for maintenance of blood pressure during spinal anesthesia for cesarean delivery. Anesthesiology 2015;122:736–45.
[4] Hocking G, Wildsmith JA. Intrathecal drug spread. Br J Anaesth 2004;93:568–78.
[5] Langesæter E, Dyer RA. Maternal haemodynamic changes during spinal anaesthesia for caesarean section. Curr Opin Anaesthesiol 2011;24:242–8.
[6] Hartwell BL, Aglio LS, Hauch MA, et al. Vertebral column length and spread of hyperbaric subarachnoid bupivacaine in the term parturient. Reg Anesth 1991;16:17–9.
[7] Norris MC. Patient variables and the subarachnoid spread of hyperbaric bupivacaine in the term parturient. Anesthesiology 1990;72:478–82.
[8] Jawan B, Lee JH, Chong ZK, et al. Spread of spinal anaesthesia for caesarean section in singleton and twin pregnancies. Br J Anaesth 1993;70:639–41.
[9] Teh J. Breakage of Whitacre 27 gauge needle during performance of spinal anaesthesia for caesarean section. Anaesth Intensive Care 1997;25:96.
[10] Aveling W. Heavy bupivacaine has no advantage over plain bupivacaine in spinal anaesthesia for caesarean section. Int J Obstet Anesth 1999;8:260–5.
[11] Yun EM, Marx GF, Santos AC. The effects of maternal position during induction of combined spinal-epidural anesthesia for cesarean delivery. Anesth Analg 1998;87:614–8.
[12] Choi DH, Park NK, Cho HS, et al. Effects of epidural injection on spinal block during combined spinal and epidural anesthesia for cesarean delivery. Reg Anesth Pain Med 2000;25:591–5.
[13] Kiran S, Singal NK. A comparative study of three different doses of 0.5% hyperbaric bupivacaine for spinal anaesthesia in elective caesarean section. Int J Obstet Anesth 2002;11:185–9.
[14] Stroumpoulis K, Stamatakis E, Koutroumanis P, et al. Pencil-point needle bevel direction influences ED50 of isobaric ropivacaine with fentanyl in spinal anesthesia for cesarean delivery: a prospective, double-blind sequential allocation study. Int J Obstet Anesth 2015;24:225–9.
[15] Lee YH, Wang YC, Wang ML, et al. Relationship of abdominal circumference and trunk length with spinal anesthesia level in the term parturient. J Anesth 2014;28:202–5.
[16] Hwang JW, Oh AY, Song IA, et al. Influence of a prolonged lateral position on induction of spinal anesthesia for cesarean delivery: a randomized controlled trial. Minerva Anestesiol 2012;78:646–52.
[17] Harten JM, Boyne I, Hannah P, et al. Effects of a height and weight adjusted dose of local anaesthetic for spinal anaesthesia for elective caesarean section. Anaesthesia 2005;60:348–53.
[18] Carvalho B, Collins J, Drover DR, et al. ED(50) and ED(95) of intrathecal bupivacaine in morbidly obese patients undergoing cesarean delivery. Anesthesiology 2011;114:529–35.
[19] Ekeløf NP, Jensen E, Poulsen J, et al. Weight gain during pregnancy does not influence the spread of spinal analgesia in the term parturient. Acta Anaesthesiol Scand 1997;41:884–7.
[20] Wei CN, Zhang YF, Xia F, et al. Abdominal girth, vertebral column length and spread of intrathecal hyperbaric bupivacaine in the term parturient. Int J Obstet Anesth 2017;31:63–7.
[21] Ousley R, Egan C, Dowling K, et al. Assessment of block height for satisfactory spinal anaesthesia for caesarean section. Anaesthesia 2012;67:1356–63.
[22] Carvalho B, Durbin M, Drover DR, et al. The ED50 and ED95 of intrathecal isobaric bupivacaine with opioids for cesarean delivery. Anesthesiology 2005;103:606–12.
[23] Danelli G, Zangrillo A, Nucera D, et al. The minimum effective dose of 0.5% hyperbaric spinal bupivacaine for cesarean section. Minerva Anestesiol 2001;67:573–7.
[24] McNaught A, Hallworth S. Weight adjusted spinal anaesthesia for caesarean section. Anaesthesia 2005;60:818–9.
[25] Russell IF. A comparison of cold, pinprick and touch for assessing the level of spinal block at caesarean section. Int J Obstet Anesth 2004;13:146–52.
[26] Ithnin F, Lim Y, Sia AT, et al. Combined spinal epidural causes higher level of block than equivalent single-shot spinal anesthesia in elective cesarean patients. Anesth Analg 2006;102:577–80.