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Risk prediction score for high spinal block in patients undergoing cesarean delivery: a retrospective cohort study

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Abstract

Background High spinal block is a serious complication of spinal anesthesia. However, findings regarding its associated risk factors are inconsistent, and no studies have reported a relevant risk prediction score. We aimed to determine the risk prediction score for high spinal block in patients who were induced spinal anesthesia for cesarean delivery.

Methods This retrospective cohort study was conducted at a hospital in Southern Thailand between 2019 and 2020. We recorded demographic characteristics, gestational age (GA), hyperbaric bupivacaine dose, sensory block level, pre- and post-procedure blood pressure, and birth weight. High spinal block was defined as a decrease in pinprick sensation > T4. Risk scores, adjusted odds ratios (OR), and 95% confidence intervals (CI) were determined. Risk scores were derived from the coefficients of the final multivariate logistic regression model.

Results The incidence of high spinal block was 22.4% among the 1003 parturients. Our risk prediction tool for high spinal block had a sensitivity and specificity of 76% and 49%, respectively, and was classified into high **(**> 21**)**, intermediate **(**15–21**)**, and low **(≤** 14**)** risk groups**.** The patient-related predictors were a GA < 35 weeks (OR [95% CI]: 2.31 [1.13, 4.71], score of 8), height < 150 cm (2.21 [1.11, 4.38], score of 8), and post-pregnancy body mass index > 27.5 kg/m^2 (2.68 [1.33, 5.41], score of 10). The anesthesia-related predictors were a hyperbaric bupivacaine dose > 11 mg (2.56 [1.34, 4.87], score of 9) and induction by a first-year resident (1.48 [1.05, 2.09], score of 4). The surgery-related predictors were previous cesarean delivery in labor (1.83 [1.2, 2.78], score of 6) and elective cesarean delivery (2.53 [1.57, 4.07], score of 9) compared to indication by cephalopelvic disproportion. The incidence of intraoperative hypotension was significantly higher in the high-block group than in the control group (46% vs. 25%, $p < 0.001$).

Conclusion The combination of patient- and anesthesia-related predictors played an important role in the intermediate- and high-risk groups for high sensory spinal block**.** Addressing the modifiable risk factors—a GA < 35 weeks, an optimal dose of bupivacaine, and the experience level of the spinal block performer—could minimize the risk of high spinal block during cesarean delivery**.**

Keywords High sensory block, Height block level, Spinal anesthesia, Risk prediction score

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Background

Spinal anesthesia is the common procedure for cesarean delivery [1, 2]. It requires a lower dose of intrathecal local anesthetic due to physiological changes during term pregnancy compared to that required in non-pregnant

women [3]. High spinal block is a serious complication associated with bradycardia, hypotension, blockade of motor nerves to the respiratory muscles, and altered mental status [4]. Many patient-related factors have been used to predict the spread of spinal anesthesia, with varying results.

The known predictors of high spinal block include the baricity of the local anesthetic, a higher dose of local anesthetic, and the position of the patient in relation to the baricity of the local anesthetic [5]. Younger age has been considered a risk factor for high spinal block [6]; however, other studies have not corroborated this finding [7, 8]. Although weight, height, and body mass index (BMI) have been significantly associated with higher block levels [7, 8], some studies have found no relationship between these factors [6, 9]. Intra-abdominal pressure [9] and neonatal birth weight [10] were found not to affect the level of spinal anesthesia in parturients, but another study [11] reported that a larger abdominal girth appeared to be related to high spinal block. Hence, the knowledge regarding the risk factors associated with high spinal block is inconsistent. Moreover, no studies have reported the risk prediction score of high spinal block [5–10]. Therefore, we conducted this study to examine the risk prediction score of high sensory block in patients undergoing cesarean delivery under spinal anesthesia.

Methods

This retrospective cohort study was initially conducted in November 2020 and was approved by The Institutional Ethics Committee of The Faculty of Medicine, Prince of Songkla University, Songkhla, Thailand, on April 23, 2021 (EC 64–080-8–4). The requirement for informed consent was waived by the Human Research Ethics Committee, Faculty of Medicine, Prince of Songkla University, owing to the retrospective nature of the study. The data were accessed on April 24, 2021, after obtaining approval from the Ethics Committee. All data were fully anonymized before being accessed by the investigators.

Participants

The anesthesia database from the Hospital Information System (HIS) was used to identify all parturients who underwent cesarean delivery under spinal anesthesia at Songklanagarind Hospital, Prince of Songkla University, between November 1, 2019, and October 31, 2020. High sensory level cases were searched in the HIS using a quality assurance process by nurse anesthetists. After a high anesthesia sensory level or analgesia level was identified, the researchers (BB and PB) assessed the accuracy of the data by reviewing the electronic anesthetic records (a PDF file scanned into the hospital information system). We excluded twin pregnancies to examine risk factors for singleton pregnancies.

Anesthesia practice and standard operating procedures

The routine anesthesia practices as well as the standard operating procedures for spinal anesthesia at the Songklanagarind Hospital is described. The basic parameters monitored during spinal anesthesia included noninvasive blood pressure, electrocardiography, oxygen saturation by pulse oximetry, urine output, and sensory block height. All spinal anesthesia procedures were performed by a resident anesthetist or by certified anesthesiologist staff. Given that Songklanagarind Hospital is a university hospital, first-year anesthesia residents with less than 1 year of experience were supervised by anesthesiologist staff. Prior to spinal anesthesia induction, 1000 mL isotonic crystalloid was administered to every parturient. Spinal anesthesia procedures were performed with the patient in the lateral decubitus position, and the patient was placed in the supine position immediately after the procedure. Routinely, a 27G Quincke spinal needle was used in every parturient. However, in the case of more than two unsuccessful attempts, a larger-gauge needle was considered. Baseline blood pressure was measured before subarachnoid block administration and subsequently at 1 min intervals for 15 min. Thereafter, it was measured every 3–5 min.

Block height was tested by performers based on the loss of pinprick sensation after the spinal block, and recorded on the anesthetic record form. Data including the number of blocks, spinal block performer, approach to the block, dose of 0.5% hyperbaric bupivacaine, and dose of intrathecal morphine were extracted from anesthetic records. Routine practice entails the use of 0.5% hyperbaric bupivacaine 10–11 mg with intrathecal morphine 0.1–0.2 mg in all parturients, unless the decision is changed by certified anesthesiologist staff. If the parturient received more than one spinal block, the total dose of 0.5% hyperbaric bupivacaine and intrathecal morphine was documented. We derived the total ephedrine dose and total intraoperative crystalloid solution, and estimated the intraoperative blood loss. Fetal birth weight and Apgar scores at 1 and 5 min were also documented. We recorded the intraoperative time (from successful spinal block until the end of the operation), postanesthetic care unit (PACU) time, and block level before discharge from the PACU.

Outcomes of the study

The primary outcome was the incidence of high spinal block. A high spinal block was defined as a loss of pinprick sensation (anesthesia) at T4 or higher or a decrease in pinprick sensation (analgesia) higher than T4, 15

min after spinal anesthesia induction [12]. The secondary outcomes were the possible complications of high spinal block. The possible sequence after high spinal block—hypotension (defined as a decrease in mean arterial pressure by > 30% of baseline within the first 15 min after spinal block) [13], bradycardia (HR < 60 bpm) [14], respiratory distress (SpO_2 < 95% on room air), and loss of consciousness—was reviewed. A failed spinal block was defined as one that required general anesthesia with endotracheal intubation [15]. Hypotension was managed by intravenous bolus of isotonic crystalloid and ephedrine 6 mg at the discretion of the anesthesiologist in charge.

Explanatory and potential confounding variables

The explanatory variables collected and used as potential predictors of high spinal sensory block included patient-related risk factors, surgery-related risk factors, and anesthesia-related risk factors. Patient-related risk factors included gestational age (GA), height, pre-pregnancy weight, post-pregnancy weight (weight on the day of cesarean delivery), comorbidities (preeclampsia, eclampsia, and gestational diabetes mellitus), and fetal birth weight. Surgery-related risk factors included emergency surgery and indications for emergency cesarean delivery. Anesthesia-related risk factors included the American Society of Anesthesiologists (ASA) physical status, median/paramedian approach, puncture site, bupivacaine dose, and spinal block performer. The practitioners who induced spinal anesthesia were first-, second-, and third-year anesthesia residents or certified anesthesiologist staff.

Statistical analysis

Descriptive statistics are presented as frequencies with percentages and medians with interquartile ranges. The chi-square test or Fisher's exact test was used to compare categorical variables, as appropriate. The data were analyzed for normality of distribution using Shapiro–Wilk test. The Continuous variables were compared using Student's *t*-test for normally distributed data and the Wilcoxon rank-sum test for non-normally distributed data. Collinearity diagnostics and a bivariate correlation matrix were evaluated for each variable. We used the optimal cutoff point on the receiver operating characteristic (ROC) curve to transform the continuous variables to categorical variables. Then, those cutoff points were determined if they were significantly associated with the outcome. All variables with a *p*-value < 0.2 in the univariate analysis were included in the initial multivariate logistic regression model. Using a backward selection procedure, the final regression model was determined by selecting the model with the lowest Akaike information criterion value at each step, even though some nonsignificant variables remained. Using the Youden index, the optimal cut-off point was derived from the final model. The association of each factor with the outcome was considered statistically significant if the likelihood ratio test *p*-value was < 0.05. The strengths of the associations are presented using adjusted odds ratios and 95% confidence intervals. Data were analyzed using R version 4.3.1 (R Core Team [2022], Vienna, Austria).

Risk prediction score

The risk prediction score for high spinal block was developed using the coefficients of the significant covariates in the final logistic regression model [16–18]. Scores were obtained by multiplying each coefficient by 10 and then rounding the result to the nearest integer. Model discrimination performance was examined using the area under the ROC curve, yielding a sensitivity and specificity based on the optimal cutoff point of the risk score.

Sample size determination

We estimated the prevalence of the primary outcome (high sensory block) in the exposure group (potential predictors) to be 50%, while the prevalence of the outcomes in the non-exposure group was estimated to be 14%, with a ratio of non-exposure to exposure of 5:1 using a significance level of 0.05 within a 95% confidence interval, and a power of 80%. The calculated sample sizes in the exposure and non-exposure groups were 17 and 85, respectively. The prevalence of high spinal block at our hospital was found to be approximately 20% in a retrospective review conducted in 2019. Accordingly, at least 510 participants were required to determine the risk factors. Hence, 1 year of data collection was deemed adequate to recruit 638 participants and compensate 20% for missing data.

Results

A total of 1003 singleton parturients were eligible for inclusion in the study (Fig. 1). None of the patients received an epidural in this study. High spinal block occurred in 225 (22.4%) individuals. A comparison of the baseline demographic characteristics and anesthesia-related factors is shown in Table 1. The GA, height, BMI, emergency surgery frequency, indication for cesarean delivery, and dose of hyperbaric bupivacaine were significantly different between the high-block and no-high-block groups. The hemodynamic changes and outcomes after spinal anesthesia are shown in Table 2. The high-block group had significantly lower blood pressure levels than the control group did. The incidence of intraoperative hypotension and the total crystalloid volume were significantly higher in the

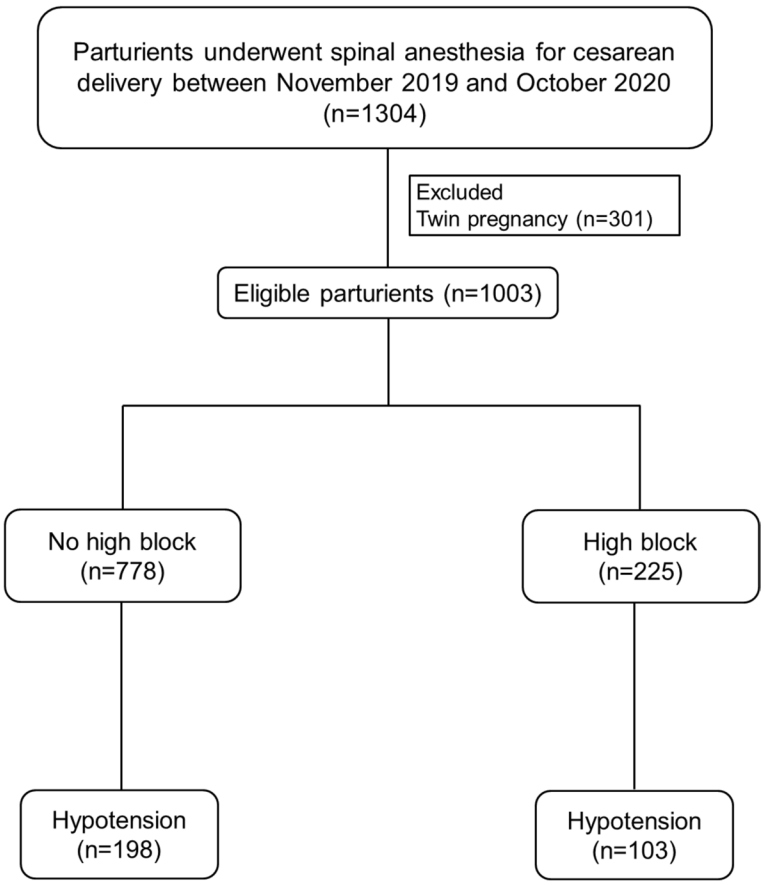

Fig. 1 Participant flow diagram

high-block group than in the control group. In the control group and high-block group, 1.3% and 1.8% of parturients, respectively, required general anesthesia for extended surgery after fetal delivery.

Figure 2 shows the average normal and high analgesia/anesthesia levels within 15 min after spinal block and before discharge. In the high-block group, the average analgesia level was T3, while the anesthesia level was approximately T4 within 15 min after spinal block. In all the groups, the levels decreased before discharge, and the regression of the spinal block level before discharge did not differ among the three groups.

Five potential patient-related factors (GA, height, pre- and post-pregnancy BMI, and birth weight), three anesthesia-related factors (puncture site, hyperbaric bupivacaine dose, and spinal block performer), and two surgery-specific risk factors (elective cases and indications for cesarean delivery) were included in the initial multivariate logistic regression model. Of these, seven remained in the final model (Table 3).

Development of the risk prediction tool

Table 3 shows the seven predictors comprising the final model and the risk scores for high spinal block. The reference group showed the lowest risk. The scores were summed to obtain individual risk scores ranging from 2 to 41. Fig. 3 shows the ROC curves of the individual risk scores for a high spinal block. The area under the curve was 0.67, and the optimal cutoff point based on the highest summation of sensitivity (76%) and specificity (49%) of the model was 21. The risk scores were then classified into three groups: high (>21), intermediate (15–21), and low (≤14) to indicate the level of high spinal block.

Discussion

The incidence of high spinal block in our study of 1:5 in parturients who underwent cesarean delivery under spinal anesthesia was significantly higher than that of 1:29,770 and 1:4336 reported elsewhere [19–21]. This difference could be attributed to the different definitions of high spinal block. Given that dermatome testing after

Table 1 Demographic data and anesthesia-related factors ($N=1003$)

Variables	No high block ($n=778$)	High block ($n=225$)	*p* value
Age (years)	33 (30, 36)	33 (30, 37)	0.252
Gestational age (weeks)	38.6 (37.9, 39.3)	38.4 (37.9, 39)	0.030*
≥ 35 weeks	752 (96.7)	211 (93.8)	0.080
< 35 weeks	26 (3.3)	14 (6.2)	
ASA physical status			0.333
II	741 (95.2)	210 (93.3)	
III	37 (4.8)	15 (6.7)	
Co-morbidities	126 (16.2)	35 (15.6)	0.90
Preeclampsia	38 (4.9)	8 (3.6)	0.51
GDM	98 (12.6)	30 (13.3)	0.858
Pre-pregnancy BMI (kg/m^2)	23 (20.7, 26)	24.1 (21.6, 26.8)	< 0.001*
< 18.5	331 (42.5)	77 (34.2)	0.002**
18.5–22.9	54 (6.9)	6 (2.7)	
23–27.4	273 (35.1)	92 (40.9)	
≥ 27.5	120 (15.4)	50 (22.2)	
Height (cm)	158 (155, 163)	157 (154, 160)	0.003*
≥ 150	750 (96.4)	209 (92.9)	0.037**
< 150	28 (3.6)	16 (7.1)	
Post-pregnancy BMI (kg/m^2)	27.4 (25.2, 30.7)	28.7 (26.5, 32)	< 0.001*
< 23	70 (9)	10 (4.4)	< 0.001**
23–27.4	322 (41.4)	61 (27.1)	
≥ 27.5	386 (49.6)	154 (68.4)	
Emergency surgery	630 (81)	162 (72)	0.005**
Indication for cesarean delivery			0.003**
CPD/abnormal presentation/failed induction	272 (35)	51 (22.7)	
Fetal distress/abnormal fetus	100 (12.9)	28 (12.4)	
Maternal co-morbidity (pre-eclampsia/eclampsia/GDM)	77 (9.9)	24 (10.7)	
Previous cesarean delivery in labor	208 (26.7)	69 (30.7)	
Elective/other	121 (15.6)	53 (23.6)	
Spinal block performer			0.049**
Staff	311 (40)	70 (31.1)	
Second- or third-year resident	95 (12.2)	29 (12.9)	
First year resident	372 (47.8)	126 (56)	
Approach			1
Median	770 (99)	223 (99.1)	
Paramedian	8 (1)	2 (0.9)	
Puncture site			0.133
L2–3	2 (0.3)	0 (0)	
L3–4	776 (99.7)	224 (99.6)	
L4–5	0 (0)	1 (0.4)	
Hyperbaric bupivacaine dose			0.049**
< 11 mg	81 (10.4)	13 (5.8)	
≥ 11 mg	697 (89.6)	212 (94.2)	
Intrathecal morphine (mg)	0.2 (0.2, 0.2)	0.2 (0.2, 0.2)	0.769
Number of spinal blocks performed			1
One	741 (95.2)	214 (95.1)	
Two	37 (4.8)	11 (4.9)	
Birth weight (g)	3104.5 (2823.2, 3394.8)	3180 (2875, 3428)	0.072
≤ 3600	688 (88.4)	189 (84)	0.098
> 3600	90 (11.6)	36 (16)	

Table 1 (continued)

Data are presented as number (%) and median (interquartile range), unless stated otherwise

ASA American Society of Anesthesiologists, *BMI* body mass index, *CPD* cephalopelvic disproportion, *GDM* gestational diabetes mellitus

* Wilcoxon rank-sum test

** Chi-square test

Table 2 Outcomes of spinal anesthesia ($N = 1003$)

Variables	No high block ($n = 778$)	High block ($n = 225$)	*p* value
Baseline SBP (mm Hg)	125 (115,140)	125 (115, 135)	0.201
Baseline DBP (mm Hg)	80 (70, 90)	80 (70, 85)	0.729
Baseline MAP (mm Hg)	93 (87, 103)	95 (87, 102)	0.461
Lowest SBP in 15 min (mm Hg)	95 (85, 105)	85 (80, 95)	< 0.001*
Lowest DBP in 15 min (mm Hg)	50 (45, 60)	48 (40, 55)	< 0.001*
Lowest MAP in 15 min (mm Hg)	65 (58, 73)	60 (55, 67)	< 0.001*
Total ephedrine dose (mg)	0 (0, 12)	12 (0, 24)	< 0.001*
Intraoperative complications			
Hypotension	198 (25.4)	103 (45.8)	< 0.001**
Bradycardia	43 (5.5)	11 (4.9)	0.837
Respiratory distress	17 (2.2)	11 (4.9)	0.053
Altered consciousness	0 (0)	1 (0.4)	0.508
Failed spinal block	10 (1.3)	4 (1.8)	0.817
Total crystalloid solution (mL)	1700 (1450, 1900)	1700 (1500, 1900)	0.023*
Total crystalloid solution (mL), mean (SD)	1713.2 (383.7)	1806.28 (508.1)	0.011***
Estimated blood loss (mL)	350 (300, 500)	400 (300, 500)	0.117
Duration of surgery (min)	70 (55, 85)	65 (55, 80)	0.989
PACU time (min)	55 (36.2, 70)	50 (35, 65)	0.074
Apgar score at 1 min	9 (8, 9)	9 (8, 9)	0.891
Apgar score at 5 min	9 (9, 9)	9 (9, 9)	0.626

Data are presented as number (%) and median (interquartile range), unless stated otherwise

DBP diastolic blood pressure, *MAP* mean arterial pressure, *PACU* postanesthetic care unit, *SBP* systolic blood pressure

* Wilcoxon rank-sum test

** Chi-square test

*** Student's *t*-test

spinal anesthesia is rather subjective, studies have used different definitions of high spinal block, such as total spinal anesthesia [20], the requirement for general anesthesia [21], or the requirement for tracheal intubation [19], which results a lower incidence of high spinal block. As there is no definite definition of high spinal block, we have defined it as a block reaching a spinal level higher than that usually required for cesarean section [12]. Given that the spinal analgesia sensory level of at least T4 or a lower anesthesia sensory level at T6 can also prevent visceral pain and discomfort during cesarean delivery [22, 23], we used an analgesic block level higher than T4 or an anesthetic block height of at least T4 to define high spinal block in our study. The incidence of the requirement for general anesthesia conversion in our study was 1.4% (14/1003) or 1:72, which was higher than that reported by D'Angelo et al. [21], as the requirement for general anesthesia conversion resulted from a failed spinal block rather than from the consequence of a high/total spinal block. In terms of extended surgery, which brought about a prolonged duration after fetal delivery, the incidence of failed spinal block did not differ between the no high block and high-block groups because the regression of the block level was similar (Fig. 2).

Risk prediction tool for high spinal block

The risk prediction score for high spinal block yielded an area under the ROC curve of 0.67 with a modest sensitivity of 76% for closer monitoring of intermediate-to-high risk scores. The optimal cut-off point from the ROC curve was 21. Therefore, we classified parturients with a score > 21 as high risk. A score ≤ 14 showed a high sensitivity (97%), which was consistent with a low false-negative rate and corresponded to a < 4% chance of high

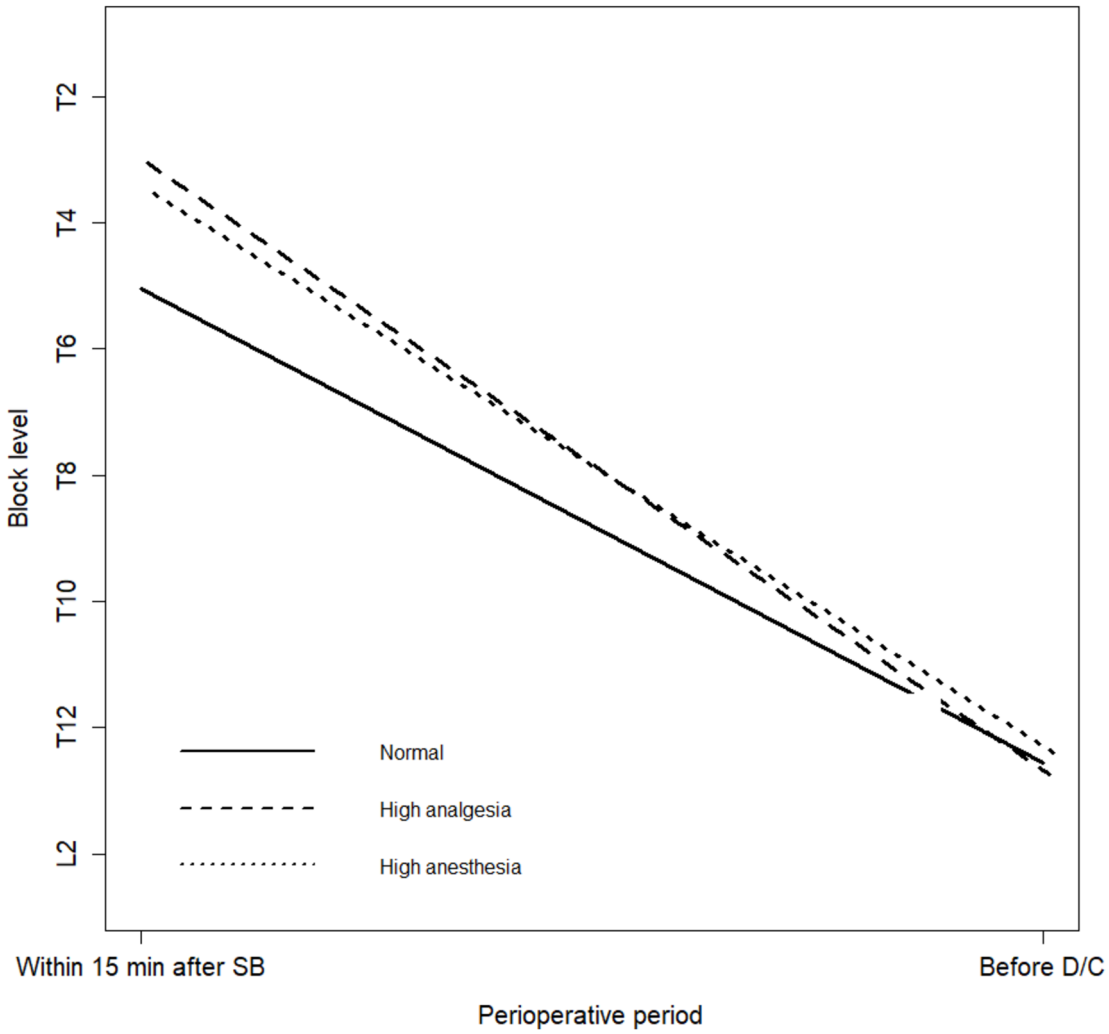

Fig. 2 Average sensory block levels in no high spinal block (normal) and high-spinal-block groups. *SB* spinal block, *D/C* discharge

spinal block occurring. Thus, a risk score between 15 and 21 was considered intermediate risk.

Intermediate-to-high risk group

There was no sole risk factor that could classify a parturient into the high-risk group (risk score > 21); at least two patient-related risk factors combined with one surgery- or anesthesia-related risk factor are needed. For example, a height < 150 cm (score of 8) with a BMI > 27.5 kg/m^2 (score of 10) and the requirement for surgery from a previous cesarean delivery (score of 6)/an elective case (score of 9) can provide a high risk score of 24. A lower height was significantly associated with a higher spinal block level, a result supported by two previous studies [23, 24]. She et al. [23] found that a shorter body height (< 158 cm) was associated with a significantly higher block level than a taller height was (> 165 cm) (T3 vs. T4). It was also associated with a higher incidence of hypotension (51% vs. 27%). An increase in intra-abdominal pressure from the gravid uterus and abdominal panniculus, such as in the presence of a higher abdominal circumference [25] and higher fetal weight causing a higher BMI [26], could lead to caval compression and epidural vein engorgement, causing a decrease in lumbar cerebrospinal fluid volume and a higher level of spinal block [27, 28]. Interestingly, a GA < 35 weeks was an important predictor in our study (score of 8). Campbell et al. [29] reported that the spinal anesthetic dosing for preterm cesarean delivery was unpredictable, causing the underestimation or overestimation of the optimal dose in cases of a preterm GA ≤ 35 week. This may explain the high spinal block rate observed in our study.

A history of cesarean delivery was associated with a higher block level than was cephalopelvic disproportion (CPD) in our study. Since CPD refers to the disproportion of the pelvic portion and fetal head, not to an increase in

Table 3 Prediction score of high spinal block by multivariate logistic regression analysis ($N = 1003$)

Predictor	Beta coefficient	Adjusted OR (95% CI)	*p* value	Risk score
Gestational age < 35 weeks	0.84	2.31 (1.13, 4.71)	0.022	8
Height < 150 cm	0.79	2.21 (1.11, 4.38)	0.023	8
Post-pregnancy body mass index (kg/m^2) (ref ≤ 23)			< 0.001	
23 to < 27.5	0.22	1.25 (0.60, 2.60)	0.546	2
≥ 27.5	0.99	2.68 (1.33, 5.41)	0.006	10
Indication for cesarean delivery (ref = CPD)			0.002^{LR}	
Fetal distress	0.43	1.53 (0.89, 2.62)	0.122	4
Pre-eclampsia/eclampsia/GDM	0.35	1.42 (0.8, 2.52)	0.238	4
Previous cesarean delivery in labor	0.60	1.83 (1.2, 2.78)	0.005	6
Elective/other	0.93	2.53 (1.57, 4.07)	< 0.001	9
Spinal block performer (ref = staff)			0.048^{LR}	
Second- or third-year resident	0.02	1.02 (0.59, 1.76)	0.941	0
First-year resident	0.39	1.48 (1.05, 2.09)	0.025	4
Hyperbaric bupivacaine dose ≥ 11 mg	0.94	2.56 (1.34, 4.87)	0.002	9
Birth weight > 3600 g	0.36	1.43 (0.92, 2.23)	0.114	4

p value by Wald's test. ^{LR} *p* value by likelihood ratio test

CI confidence interval, *CPD* cephalopelvic disproportion, *GDM* gestational diabetes mellitus, *Ref* reference, *OR* odds ratio

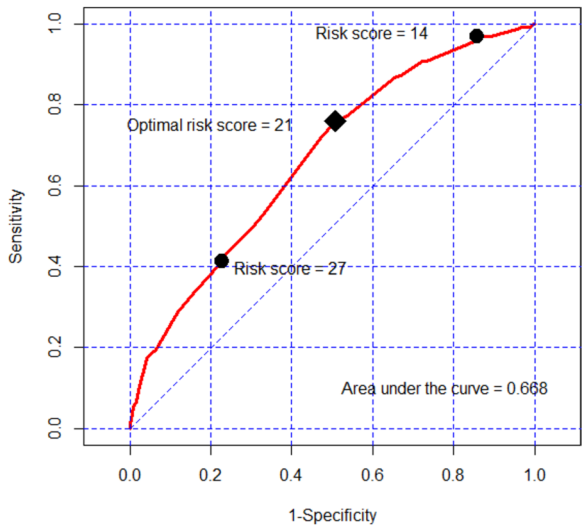

Fig. 3 Receiver operating characteristic curve of the risk score model for predicting high spinal block

intra-abdominal pressure, it is also an emergency condition with maternal labor pain, which could lead to stress in both the parturient and spinal block performers. A higher frequency and accuracy of analgesic/anesthetic block level assessment may be more common in parturients who were induced elective spinal anesthesia than in those with a CPD emergency condition, which could lead to the interpretation of a higher level of spinal block. A higher dose of bupivacaine > 11 mg (score of 9) was associated with a higher spinal block level, a result supported by previous studies [30]. A fetal birth weight > 3600 g was one of our risk predictors (score of 4), which was supported by the findings of Shitemaw [31], revealing that a higher fetal weight was associated with hypotension, which arose from a higher spinal block. Induction by a trainee (first-year resident) (score of 4) was also associated with a high block, consistent with the findings of Shitemaw et al. [31] that an inexperience performer could not prevent high spinal block occurrence early by changing the patient's position nor manage hemodynamic instability.

Clinical implication in anesthesia practice

High spinal blocks are harmful as they are associated with hemodynamic instability (hypotension) [4, 31] and a higher incidence of respiratory depression (4.9% vs. 2.2%) than that experienced in individuals without high spinal block [32]. However, complications such as bradycardia, altered consciousness, and failed spinal blocks did not differ between the two groups. Therefore, a spinal block > T4 should be performed with caution because an anesthetic block level (loss of pinprick sensation) of at least T6 can promote pain relief and comfort during cesarean delivery, especially when the fetus is delivered [17]. The risk prediction score of high spinal block can be applied to minimize intermediate- (15–21) to low-risk scores (≤ 14), for example, by avoiding high doses of bupivacaine (> 11 mg) (score of 9) and involving an experienced spinal block performer. The use of a height-based dosing algorithm for bupivacaine administration can be useful [33]. Although many risk factors

cannot be prevented, for instance, a high BMI, high fetal weight, and GA < 35 weeks, one should be aware of high spinal block (> T4); be prepared to minimize the risks for adverse events, such as preoperative fluid loading; and focus on maintaining hemodynamic stability, thereby promoting maternal well-being during cesarean delivery.

Strengths and limitations

The strengths of this study are as follows: First, we used a multivariate logistic regression model to predict high spinal block, adjusted for potential confounding variables**.** For the risk prediction tool, we multiplied each coefficient by 10 to maximize the risk score and obtain the highest ROC [12]. Second, the sample size was adequate and there were no missing data. However, this study has some limitations. First, the nature of a retrospective cohort study entails information bias in some data. For example, the use of barbotage and speed of injection, which can impact the spread of the drug and the level of the spinal block [34], could not be defined. Moreover, assessment of the maximum block height after 15 min could lead to the misclassification of outcomes, therefore, we assessed the average block levels between the no high block and high-block groups to determine the accuracy of the block height. Second, hemodynamic changes in blood pressure and heart rate were not considered due to limitations in the anesthetic records and vital-sign data. Third, due to the large sample size that resulted in a statistically but not clinically significant difference in some risk factors, such as height, gestational age, and total volume of crystalloids, clinicians should be more careful for the clinical implications. However, the optimal cut-off point of those risk factors that arrived from the ROC curve would help clinicians to differentiate those risk factors, for example, height < 150 vs. ≥ 150 cm, gestational age < 35 weeks vs. ≥ 35 weeks. Furthermore, the generalizability of our results is limited because the study participants were recruited from a single hospital.

Conclusions

According to recent anesthesia practices, some controversial factors, such as BMI, height, and fetal birth weight, were found to be important predictors of high spinal block. Importantly, premature parturition (GA < 35 weeks) served as an intermediate risk predictor in combination with surgery- and anesthesia-related factors. To minimize the risk of high spinal block, patient-related risk factors could be modified by inhibiting preterm labor until > 35 weeks, while anesthesia-related risk factors could be modified by limiting the bupivacaine dose and involving experienced spinal anesthesia performers**.**

Abbreviations

ASA	American Society of Anesthesiologists
BMI	Body mass index
CPD	Cephalopelvic disproportion
GA	Gestational age
HIS	Hospital Information System
PACU	Post-anesthesia care unit
ROC	Receiver operating characteristic

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Authors' contributions

PB participated in its design and revised the draft manuscript. BBS participated in its design and collected the data. JT and SC coordinated the drafting of the manuscript. MO coordinated the study, participated in the study design, undertook the statistical analysis and wrote the draft manuscript. All authors have read and approved the final version.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The study was approved by the Human Research Ethics Committee of the Faculty of Medicine, Prince of Songkla University, Songkhla, Thailand, Chairperson Assoc. Prof. Boonsin Tangtrakulwanich, REC 64–080-8–4 on April 23, 2021. The requirement for informed consent to participate was waived.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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