Predicting the Risk of Emergency Cesarean Delivery in Nulliparous Korean Women at Term

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Abstract

Background To develop a nomogram for identifying nulliparous women at high risk of unplanned cesarean delivery (CD) during labor at term pregnancy

Methods This retrospective cohort study involves singleton pregnancies delivered between October 2008 and October 2017 at a tertiary center. We included nulliparous women at term conducting a trial of labor. We identified the risk factors for CD during labor based on logistic regression analysis and created a predictive nomogram. We assessed predictive performance with respect to calibration and validation using C-statics and calibration plot.

Results Overall, a total of 3237 nulliparous women met our inclusion criteria and were randomly divided into a training set (n = 1618) and a validation set (n = 1619). The risk due to the five preselected parameters for emergent CD during labor was as follows: advanced maternal age [adjusted odds ratio (aOR), 1.101; 95% confidence interval (CI) 1.058-1.146], higher maternal height [aOR, 0.955; 95% CI 0.928-0.983], increasing BMI [aOR, 1.147; 95% CI 1.098-1.199], fetal head circumference [aOR, 1.116; 95% CI 0.976-1.276], and fetal abdominal circumference [aOR, 1.161; 95% CI 1.055-1.276]. A nomogram was developed to indicate the individual risk of emergency CD during labor, with excellent calibration and discriminative ability, and the C-indices were 0.714 and 0.703 in the training and validation sets, respectively

Conclusions We developed a validated nomogram using five variables to identify nulliparous Asian women at high risk for CD during labor at term pregnancy. This model might be useful for counseling of individual women at risk of CD and to modify the current management protocols.

Background

The World Health Organization (WHO) stated that the ideal rate of cesarean delivery (CD) at the population level was less than 10 ~ 15% and was associated with decreased maternal and neonatal mortality [1]. However, the global cesarean rate was as high as 19.1% in 2014, which increased continuously since 1990, from 6.7–19.1% [2]. In Korea, as the proportion of elderly gravida and nulliparous women increased, the cesarean rate also increased from 36.7% in 2012 to 47.3% in 2018 [3, 4]. Although the rate of CD has increased worldwide, the increase is not a result of reduction in serious neonatal morbidity such as cerebral palsy [2, 5].

Although CD is associated with higher maternal morbidity than spontaneous vaginal delivery, the pre-labor cesarean section decreases maternal and neonatal morbidity compared with instrumental vaginal delivery or emergent cesarean section [6]. In terms of childbirth, especially involving nulliparous parturients, the main concern for obstetricians is whether vaginal delivery can be successful while minimizing maternal and neonatal complications. Predicting women at high risk for CD is important in obstetrical management to reduce maternal and neonatal morbidity.

Multiple risk factors contribute to labor failure in nulliparous women, and several models have been developed to predict the mode of delivery in these women [7–9]. However, these models were mainly aimed at Western women, and fewer Asian women were included [7–10]. Therefore, the objective of this study was to develop a validated predictive model that could be used to counsel East Asian nulliparous women.

Materials And Methods

This study was a retrospective cohort study conducted in singleton nulliparous women who delivered between Oct 2008 and Oct 2017 at Seoul St. Mary's hospital. We included nulliparous women with term, cephalic presentation. Exclusion criteria were: CD due to non-cephalic presentation, abnormal placentation, disproportionate cephalopelvic size, maternal or fetal problemss, and elective CDs on maternal request and CDs prior to labor onset or active phase (cervical dilatation less than 3 cm with uterine contraction). Delivery of babies weighing less than 2.5 kg or presenting with macrosomia greater than 4 kg was also excluded. Maternal complications of diabetes or gestational diabetes, moderate-to-severe PIH or PAH, or other significant complications were excluded. Hyper- or hypothyroidism, mild hypertensive disease or ITP were not excluded. The study population framework illustrating the total number of births assessed is presented in Fig. 1.

We extracted medical information from chart review. Gestational age was calculated from the first day of last menstrual period and corrected with ultrasonographic information of crown rump length during the first trimester. BMI was calculated using maternal weight and height measured on the admission day for delivery. Ultrasonographic findings were based on fetal biometry within one week before delivery. Fetal biometry data included fetal head and abdominal circumference, and estimated fetal weight calculated using the Hadlock-3 formula.

Baseline characteristics of women who successfully delivered vaginally and those who underwent emergency cesarean section during labor were compared. Continuous variables were compared using Student's *t* test and categorical variables by Chi-square test or Fisher's exact test. The primary endpoint of this study was emergent cesarean section during labor.

To develop the predictive model, we preselected risk factors based on data obtained from published predictive models [7–10]. The preselected risk factors include: indicated maternal age, body mass index (BMI) at delivery, fetal head circumference (HC) and abdominal circumference (AC). Univariate and multivariate logistic regression analyses were performed to assess the association between preselected risk factors and cesarean section during labor.

The study population was randomly assigned via proportional stratified sampling to a training set for developing a predictive model and a validation set [11]. We developed a predictive nomogram for CD during labor using the multiple logistic regression model. The predictive nomogram was run using the validation set to assess the performance of the model. Model performance was quantified with respect to discrimination and calibration. Internal validation was carried out by resampling with replacement using

the bootstrapping method (200 repetitions) to correct for optimistic bias. Calibration plots were constructed by plotting the predicted probabilities from the nomogram against actual probabilities to determine the adequacy of calibration. We used C-statitics to assess discrimination performance.

The Institutional Review Board of the Catholic University of Korea approved the present study (XC20WIDI0103) and granted an exemption from the requirement of informed consent because of the retrospective nature of study and lack of clinical intervention or follow-up. All data were anonymous and we performed the study in accordance with the Declaration of Helsinki. The analyses were performed using SAS for Window version 9.2 (SAS Institute, Cary, NC, USA) and R package with Design, Hmisc, and Lexis libraries (http://lib.stat.cmu.edu/ R/ CRAN/) [12].

Results

During the study period, a total of 10838 pregnant women delivered at Seoul St. Mary's hospital. Overall, a total of 4834 nulliparous women with singleton pregnancies delivered at term during the study period, and 266 pregnancies were excluded due to fetal factors such as low birth weight, major fetal anomalies, and non-reassuring fetal heart rate or macrosomia. The indicated CDs (n = 1362) due to abnormal placentation, non-cephalic presentation, previous myomectomy or a history of uterine scar, and wanted cesarean section before active phase labor (n = 307) were excluded. Then, 240 pregnancies were excluded due to maternal complications such as moderate-to-severe pregnancy-related hypertension or severe preeclampsia, diabetes or gestational diabetes, or other significant complications. After further exclusion of 35 pregnancies with missing data, a total of 3237 women were included in the final analysis.

The maternal baseline characteristics are listed in Table 1.From a total cohort of 3237 nulliparous women, 521 (19.2%) underwent emergency CD during labor. The indications for cesarean section during labor were non-reassuring fetal status (n = 141) and arrest of labor progression (n = 380). The study population was randomly divided into the training set (n = 1618) and the validation set (n = 1619) as shown in Fig. 1.

Table 1
Maternal and fetal characteristics of the study population.

Characteristics	Successful vaginal delivery	Emergent cesarean delivery during labor	
	(n = 2716)	(n = 521)	*p* value
Maternal age, y	31.5 ± 3.4	32.7 ± 3.7	< 0.001
Gestational age, w	39.1 ± 1.0	39.3 ± 1.0	< 0.001
Height, cm	162.4 ± 4.9	161.2 ± 5.2	< 0.001
Weight at delivery, kg	66.4 ± 8.4	69.2 ± 9.5	< 0.001
Weight at pre-pregnancy, kg	53.3 ± 7.2	55.3 ± 8.7	< 0.001
BMI at delivery, kg/m^2	25.1 ± 2.9	26.6 ± 3.3	< 0.001
BMI at pre-pregnancy, kg/m^2	20.2 ± 2.4	21.2 ± 3.1	< 0.001
Male neonate	1374 (50.6)	292 (56.1)	0.022
Birth weight, g	3180.9 ± 310.8	3323.7 ± 335.0	< 0.001
Estimated fetal weight, g	3201.4 ± 326.7	3347.3 ± 373.9	< 0.001
Head circumference, cm	33.0 ± 1.2	33.3 ± 1.2	< 0.001
Abdominal circumference, cm	33.2 ± 1.6	33.9 ± 1.8	< 0.001
Apgar 1 min	8.1 ± 1.2	7.3 ± 1.6	< 0.001
Apgar 5 min	9.3 ± 0.9	8.8 ± 1.2	< 0.001
Epidural anesthesia	2105 (77.5)	324 (62.2)	< 0.001
Labor induction	1273 (46.9)	367 (70.4)	< 0.001

Data was described as mean ± standard deviation and number (%), *BMI* body mass index

In a logistic regression analysis using a training set, the preselected variables were associated with CD during labor: maternal age, height, BMI at delivery, fetal HC and fetal AC measured within one week before delivery. The best combined predictors are described in Table 2. In multivariate analysis, the risk of each parameter was as follows: 1) maternal age (adjusted Odd Ratio (aOR), 1.101; 95% CI 1.058–1.146), 2) maternal height (aOR, 0.955; 95% CI 0.928–0.983), 3) BMI at delivery (aOR, 1.147; 95% CI 1.098–1.199), 4) fetal HC (aOR, 1.116; 95% CI 0.976–1.276), and 5) fetal AC (aOR, 1.161; 95% CI 1.055–1.276). Although the HC was not significantly associated with cesarean section during labor in multivariate analysis, we included it to improve the performance of the predictive nomogram.

Table 2
Univariate and multivariate analysis of preselected parameters associated with emergent Cesarean delivery during labor.

	Univariate analysis		**Multivariate analysis**	
	OR (95% CI)	***p* value**	**aOR(95% CI)**	***p* value**
Maternal age (year)	1.106 (1.065–1.148)	< *0.001*	1.101 (1.058–1.146)	< 0.001
Height (cm)	0.954 (0.928 – 0.890)	< 0.001	0.955 (0.928–0.983)	0.002
BMI at delivery (kg/m^2)	1.184 (1.136–1.235)	< 0.001	1.147 (1.098–1.199)	< 0.001
Head circumference (cm)	1.219 (1.083–1.372)	0.001	1.116 (0.976–1.276)	0.109
Abdominal circumference (cm)	1.273 (1.169–1.386)	< 0.001	1.161 (1.055–1.276)	0.002

OR odds ratio, *aOR* adjusted odds ratio, *BMI* body mass index.

A predictive nomogram was developed for individualized risk assessment based on five parameters as described in Fig. 2. The total point scores ranged from 131 to 233. For example, a woman who is 34 years old (43 points), 155 cm in height (33 points), with a BMI of 30 kg/m^2 (50 points) at delivery, an estimated fetal HC of 35 cm (32 points), and a fetal AC of 35 cm (33 points) scored 191 total points, representing an approximately50%.likelihood of cesarean section during labor.

The derived prediction nomogram showed a C-index of 0.714(95% CI: 0.712 ~ 0.716) in the training set. We performed an internal validation with bootstrapping method (200 repetitions) to correct for optimistic bias. The calibration curve for CD during labor in the training set showed a good fit with the reference curve. Predicted probabilities agreed with actual probabilities observed (Fig. 3a).The C-index for the nomogram in the validation set was 0.703 (95% CI: 0.701 ~ 0.705). The calibration curve for the validation set showed goodness of fitness up to approximately 40%, after which the model over-predicted the risk of cesarean section during labor (Fig. 3b).

Discussion

Our study demonstrated that five simple parameters, including maternal age, height, BMI, fetal HC, and AC measured within one week before delivery, can be used to assess the risk of CD during labor in nulliparous women. These parameters have been associated with the risk of a failed vaginal delivery during labor in several published studies [13–15]. Burke et al. combined these parameters to establish the predictive model and assess the risk of unplanned cesarean section during labor in nulliparous women [8]. They created a predictive nomogram using similar parameters and suggested that their model has potential to offer individualized counseling and provides a reasonable option for women to undergo successful vaginal delivery [8]. However, this model was mainly targeted at white Europeans, and showed that other ethnic groups had a higher risk of emergent cesarean section during labor than the white European group. In contrast to the model of Burke et al., we use sonographic parameters measured within one week before delivery and included all nulliparous women after 37 weeks of gestation. It is suggested that the labor induction at 39 weeks reduces the rate of CD without increasing the risk of neonatal morbidity in low-risk nulliparous women [16]. Our nomogram included sonographic fetal sizes measured within a week of delivery. Sonographic information measured within a week before delivery was expected to provide useful information in planning labor induction before the 39th week of gestation in low-risk nulliparous women.

Our nomogram yielded slightly better performance than the previous published model [8]. In addition, the nomogram in this study incorporated older maternal age, and wider ranges of BMI, height, HC, and AC. Because maternal age is higher in Korea and advanced maternal age is an independent risk factor for emergency cesarean section, a nomogram is needed for pregnant women aged above 40 years [17]. In addition, several studies reported that pre-pregnancy overweight and obesity are closely related to adverse obstetric outcomes including CD or obstetric procedures [18, 19].Although the WHO classification of BMI for Asian women is modified from that of Western population, obesity and dispersion in the BMI distribution of Asians have been increased [20–23].Therefore, a nomogram with further dispersion in the range of parameters may yield better performance.

The risk of cesarean section for dystocia increases with increased neonatal birth weight [24]. The estimated fetal weight was associated with the risk of cesarean section during labor; however, we used the fetal HC and AC separately in the predictive model instead of the estimated fetal weight. Although the accuracy of ultrasound-based fetal weight estimation has improved in recent decades, the estimated fetal weight is inconsistent with actual birth weight [25, 26]. The size of fetal head or abdomen alone is strongly correlated with actual birth weight than the estimated fetal weight [15, 27]. Stirnemann et al. suggested that fetal size should be assessed using a separate biometric measure as well as the estimated fetal weight, to avoid a minimalist approach to a single value [25]. We agree that separate biometric measurement may be more reproducible and show consistent predictive power rather than the calculated value.

Our study has some limitations. This study was a retrospective cohort study. However, we tried to include all consecutive mothers who delivered during the study period to reduce the selection bias. The obstetrician and patients were not blinded to the sonographic information obtained via fetal biometry. The estimation itself or knowledge of the fetal weight may influence the rate of cesarean section, regardless of actual birth weight [28]. This information may have influenced the obstetrician's decision regarding the mode of delivery and timing of labor induction. The rate of labor induction in our study population was high at 50.6%. However, the gestation age of most women in our cohort was greater than 39 weeks, and a recent study suggested that it is reasonable to induce labor after this gestational age in low-risk women [16].

We could not perform external validation using an independent dataset. It may be a weakness of this study. The performance of the nomogram evaluated using the validation set showed a good fit ; however, it was relatively lower than that of the training test. This model may need to be validated in different institutions or other ethnic groups.

In conclusion, we have shown that maternal age, height, BMI at delivery, and fetal HC and AC were associated with the risk of CD during labor in nulliparous women. A predictive nomogram based on these parameters might be useful for counseling an individual parturient on the risk of cesarean section and for modifying management protocols. However, a further validation for other ethnic groups and women undergoing preterm labor is required.

Abbreviations

WHO
World Health Organization (WHO); CD:Cesarean delivery; BMI:Body mass index; HC:Head circumference; AC:Abdominal circumference; OR:Odds ratio.

Declarations

Ethics approval and consent: The Institutional Review Board of the Catholic University of Korea approved the present study (XC20WIDI0103) and waived the requirement of informed consent because of the retrospective nature of study and lack of clinical intervention or follow-up. All data was anonymized, therefore individual consent for publication was not required.

Consent for publication

Not applicable.

Availability of data and materials: Datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript

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Author contributions:

HSK conceived the study, analyzed the data, interpreted the results, and drafted and revised the manuscript. JHP and JYP conceived the study, collected and managed the data. IYP conceived the study, interpreted the results. YGP conceived the study, analyzed the data. JHW conceived the study, drafted the manuscript. All authors read and approved the final manuscript.

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Figures

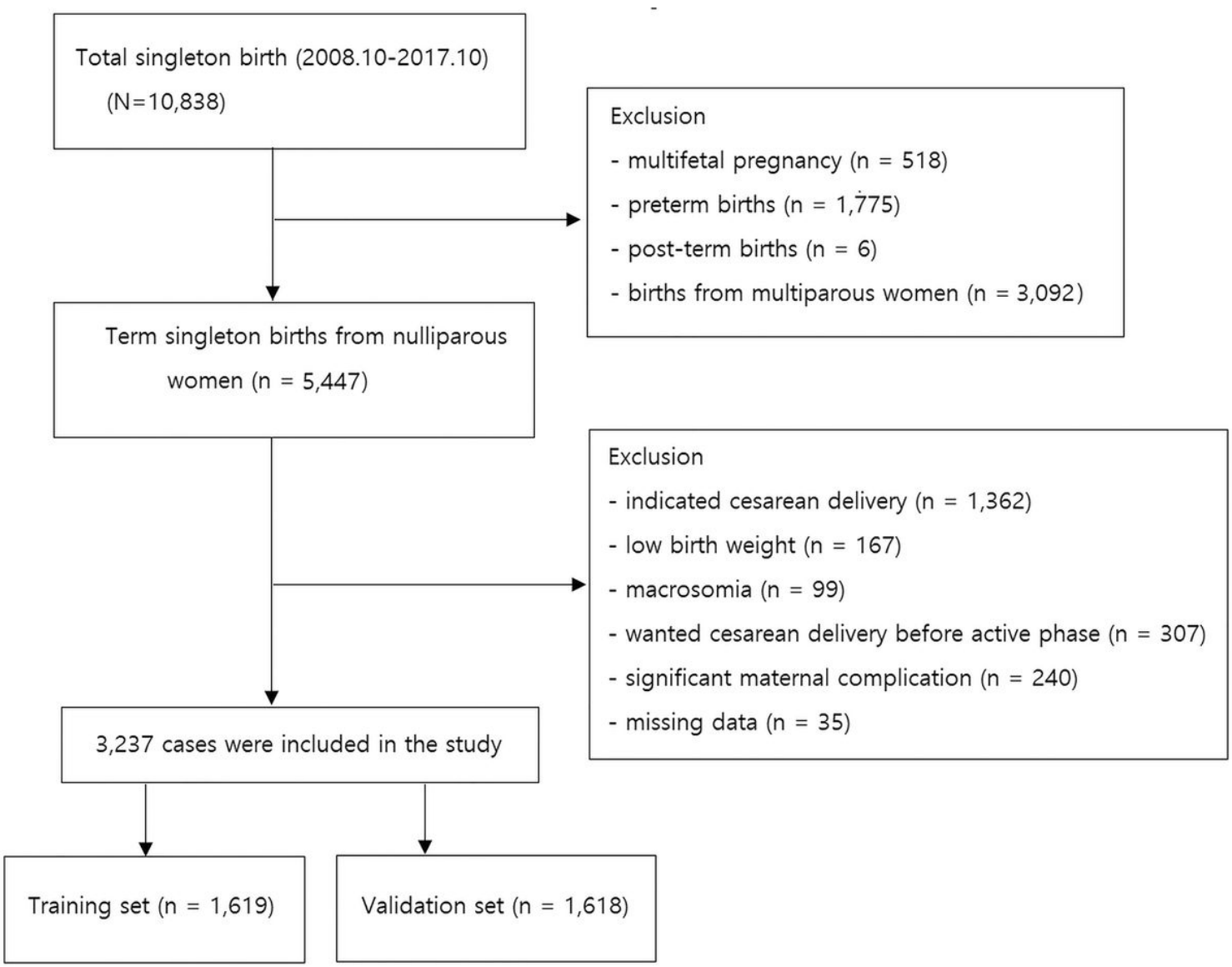

Figure 1

Flow chart of the study population.

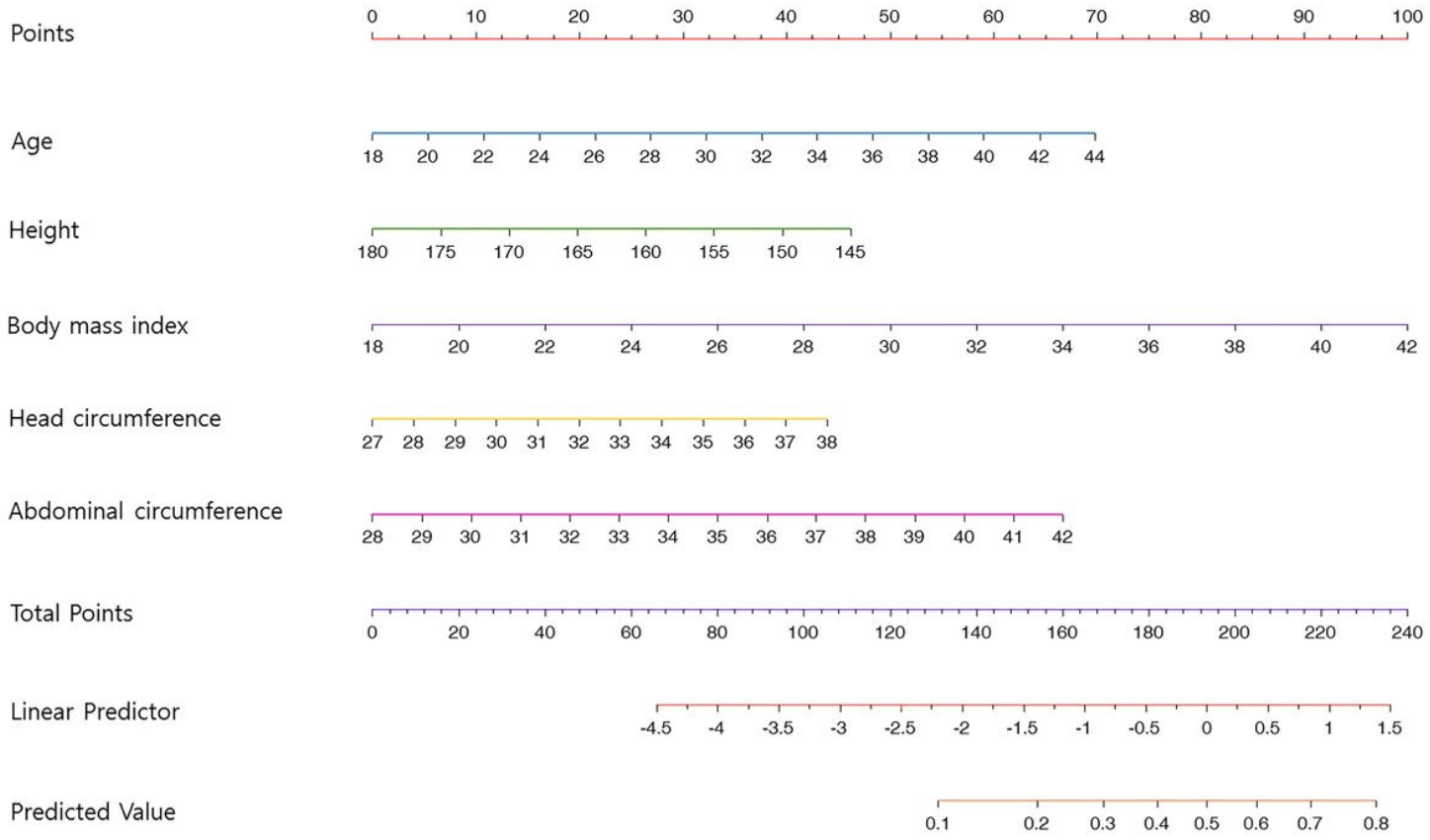

Figure 2

Nomogram to estimate the probability of the emergent cesarean section during labor

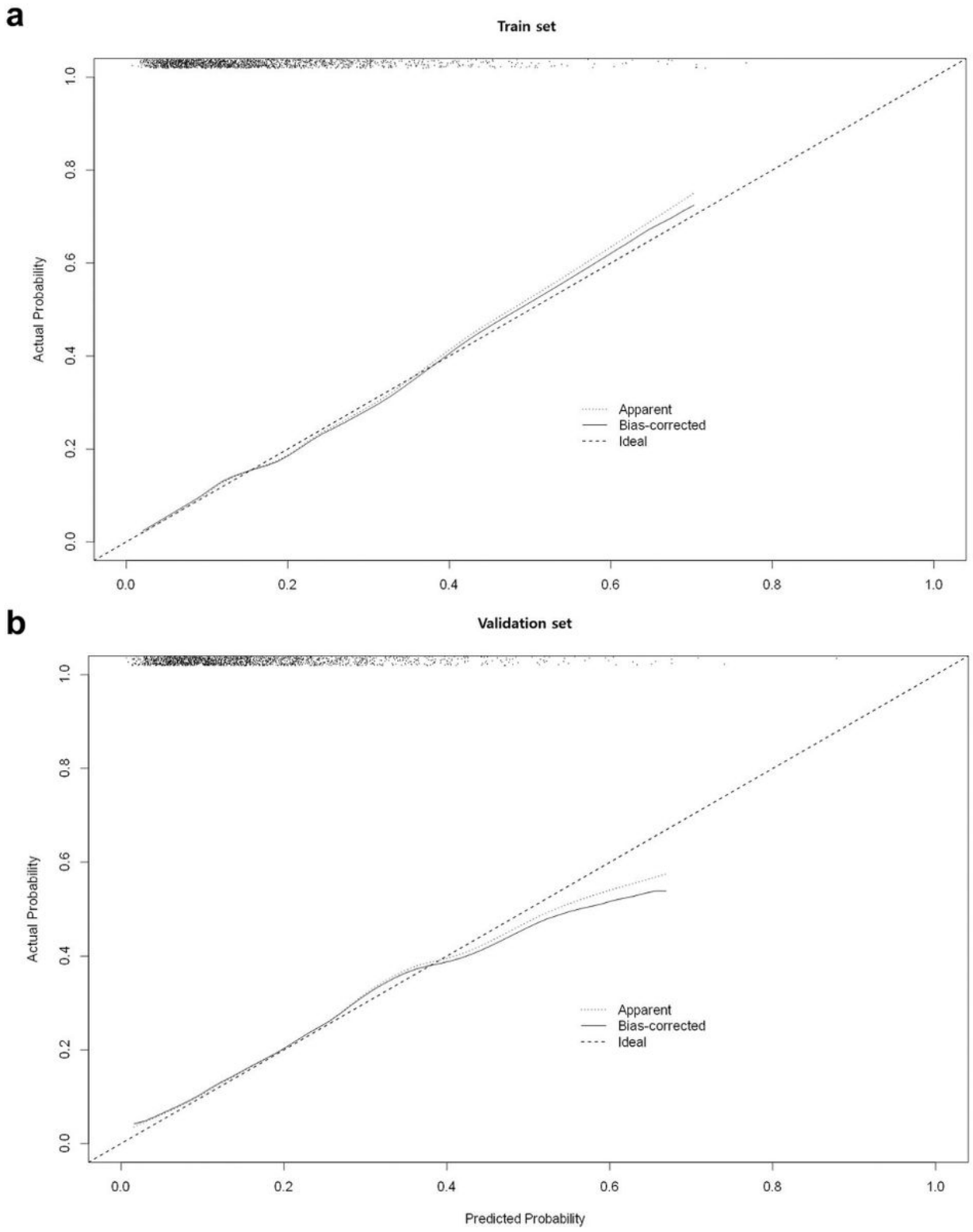

Figure 3

Calibration curve for the emergent cesarean section during labor for (a) the training set (n = 1618), (b) the validation set (n = 1619).