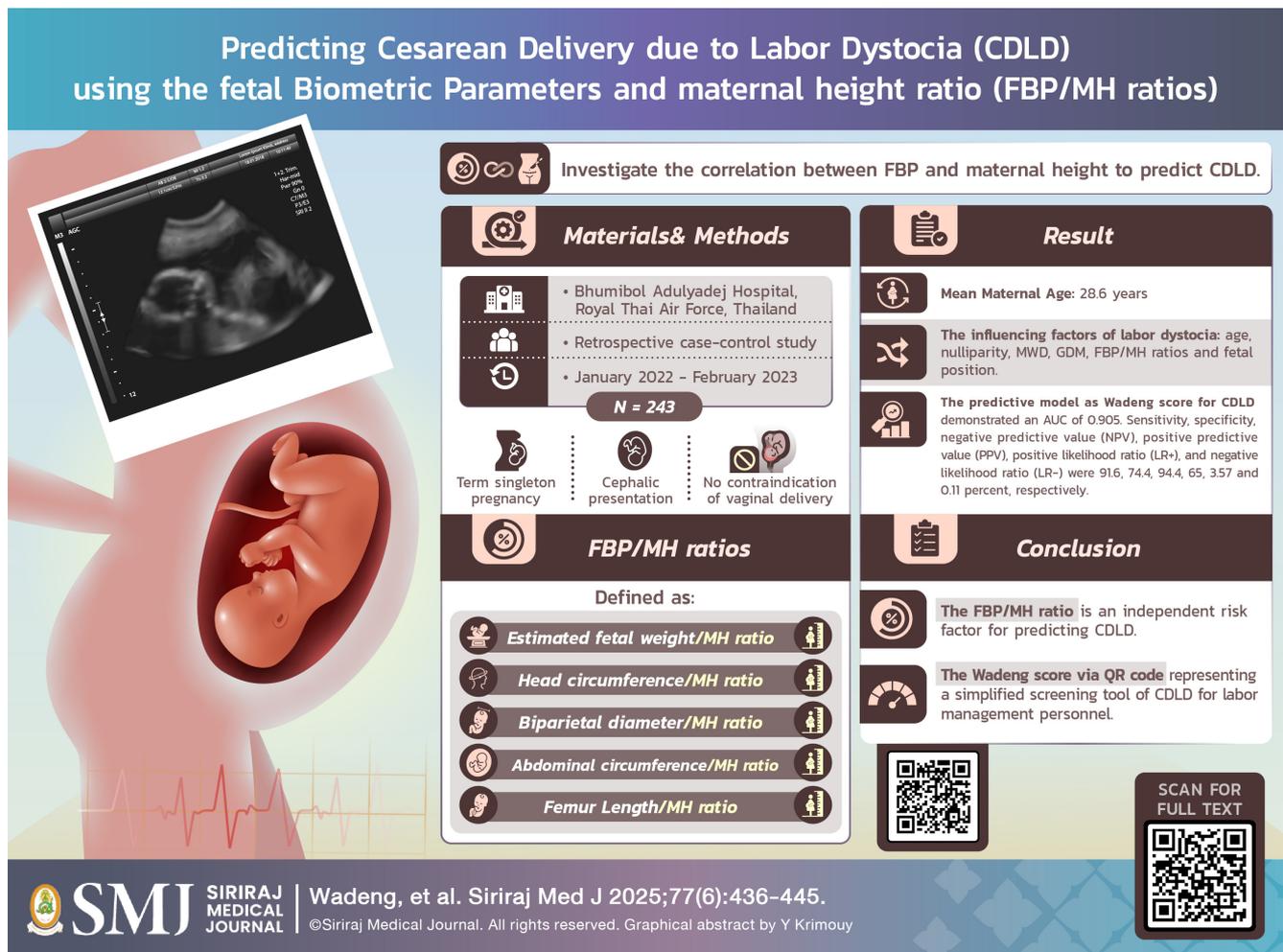


Sonographic Assessment of Fetal Biometric Parameters and Maternal Height Ratio for Prediction of Cesarean Delivery due to Labor Dystocia

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ABSTRACT

Objective: To investigate the correlation of fetal biometric parameters (FBP; estimated fetal weight (EFW), head circumference (HC), biparietal diameter (BPD), abdominal circumference (AC) and femur length (FL) and maternal height (MH) ratio to predict cesarean delivery (CD) due to labor dystocia (LD).

Materials and Methods: This retrospective case-control study was conducted at the Department of Obstetrics and Gynecology, Bhumibol Adulyadej Hospital, Bangkok, Thailand, between January 2022 and December 2023. Inclusion criteria were pregnant women with singleton, cephalic presentation, termed and without contraindication of vaginal delivery.

Results: A total of 243 parturients were included in the study, with a mean age of 28.6 years. The cesarean delivery rate was 34.1% (83/243). The predictive model was developed incorporating variables including parity, maternal age, gestational diabetes mellitus (GDM), weight, and the FBP/MH ratio. The predictive model for CD due to LD demonstrated an AUC of 0.905, indicating excellent performance. Sensitivity, specificity, negative predictive value (NPV), positive predictive value (PPV), positive likelihood ratio (LR+), and negative likelihood ratio (LR-) were 91.6, 74.4, 94.4, 65, 3.57 and 0.11 percent, respectively.

Conclusion: The FBP/MH ratio is an independent risk factor for predicting CD due to LD. The predictive model of CD due to LD gave sensitivity, specificity, NPV and PPV at percentages of 91.6, 74.4, 65 and 94.4 respectively. This model might be a simple screening tool for labor attending personnel.

Keywords: Labor dystocia; fetal biometric parameters; maternal height; cesarean delivery (Siriraj Med J 2025; 77: 436-445)

INTRODUCTION

Labor dystocia (LD), or difficult labor, is defined as abnormally slow progression or arrest of labor; it is the most common indication for primary cesarean delivery (CD) in nulliparous women when diagnosed during the birthing process. Approximately one-third of the primary cesarean indications are LD.¹⁻³ Adverse outcomes of cesarean delivery include hemorrhage, infection and neonatal compromise.⁴

The current evaluation of pelvimetry typically relies only on digital interrogation of the bony pelvis to measure cervical dilation as well as fetal and head positions during parturition. However, digital examination is a subjective method that allows for interpersonal variation among practitioners.¹

Estimated fetal weight (EFW) and fetal head circumference (FHC) have been reported to affect the odds of successful vaginal delivery. In fact, the compatibility between FHC and maternal pelvis is a key factor for successful vaginal delivery.⁵⁻⁷ A previous study proposed the use of FHC to maternal height (MH) ratio for the prediction of labor dystocia risk.⁸ Molaei (2022) reported that EFW and FHC ultrasound measurements can be used to predict the need for cesarean section and abnormal dilatation progression.⁵ However, studies regarding the Fetal Biometric Parameter (FBP) to MH ratio in predicting labor dystocia are lacking.

This study investigated the correlation and predictive tool between fetal biometric parameters and MH ratio in labor dystocia prediction. The convenience predictive model via smart phone might be generated for real world using.

MATERIALS AND METHODS**Study design**

This retrospective case-control study was conducted at the Department of Obstetrics and Gynecology, Bhumibol Adulyadej Hospital (BAH), Thailand, between January 2022 and December 2023. In 2024, this study was approved by the ethics committee of Bhumibol Adulyadej Hospital (BAH) (IRB 69/67).

Data source and study population

This study was conducted on pregnant women who gave birth at BAH between January 2022 and December 2023. The inclusion criteria were women with singleton fetuses that had reached full term (gestational age after 37 weeks) in cephalic presentation with no contraindication to vaginal delivery. Women who underwent cesarean section for any indication other than labor dystocia, namely fetal non-reassuring, fetal distress, or elective cesarean section were excluded. Women diagnosed with labor dystocia based on the American College of Obstetricians and Gynecologists (ACOG)/ Society for

Maternal-Fetal Medicine (SMFM) recommendations for the safe prevention of primary cesarean section were included when the criteria for arrest of dilatation or arrest of labor in the second stage were fulfilled.⁹

Active labor was characterized by fully effaced and at least 6 cm of cervical dilatation, with three contractions per 10 minutes as recorded by tocography. A protracted active phase occurred when, despite 6 cm dilation and ruptured membranes, labor did not progress after 4 hours of adequate uterine activity or 6 hours of oxytocin administration with inadequate contraction and no further dilatation. Arrest of labor in the second stage was diagnosed if the active phase lasted two hours in multiparous women or three hours in nulliparous women without fetal head descent.¹⁰

To enhance the model's effectiveness, missing ultrasound records of FBP, namely estimated fetal weight (EFW), fetal head circumference (FHC), fetal biparietal diameter (FBPD), fetal abdominal circumference (FAC), and fetal femur length (FFL) within the week prior to the delivery, and unqualified diagnosis of LD were excluded before analysis.

Sample size

The sample size was calculated based on the comparison between two different proportions, using the statistical software package STATA (version 18) (StataCorp, College Station, TX, USA). The data were divided into two groups: patients who had cesarean deliveries due to labor dystocia (cases) and those who had vaginal deliveries (controls) in a 1:2 ratio. The proportion of women who underwent cesarean section due to labor dystocia (CDLD) was 0.73. The proportion of women who had vaginal delivery (VD) was 0.53. Using a continuity correction, the sample size

was calculated to be 76 for cases and 152 for controls. After accounting for a 10% dropout rate, the adjusted total sample size required was 250 patients, including 84 for cases and 166 for controls to achieve 80% statistical power with a two-sided alpha error of 0.05.

Aim

The primary aim of this study was to investigate the relationship between FBP/MH ratio and CDLD. The secondary aim was to develop and validate a multiparameter risk-based system. Additionally, the study assessed the receiver operating characteristic (ROC) curve to identify cut-off points that correlate with CDLD. Accuracy, sensitivity, specificity, negative predictive value (NPV), positive predictive value (PPV), positive likelihood ratio (LR+), and negative likelihood ratio (LR-) were investigated.

Conventional statistical analysis

Statistical analysis was conducted using the STATA for MacBook, version 18. Chi-square test or Fisher's exact test was used to compare the rates of various risk factors between the CDLD and VD groups. Multivariable analysis (logistic regression) was used to explore the potential predictors of CDLD, with a p-value threshold < 0.05. Logistic coefficients were transformed into risk-based systems. Internal validation was performed by bootstrapping procedure.

RESULTS

In the study period, there were 250 cases of termed pregnant women. After exclusions, 243 subjects were recruited in the study as shown in Fig 1. The success rate of vaginal delivery was 65.9% (160/243). Subjects were divided into VD and CDLD groups. The mean age of

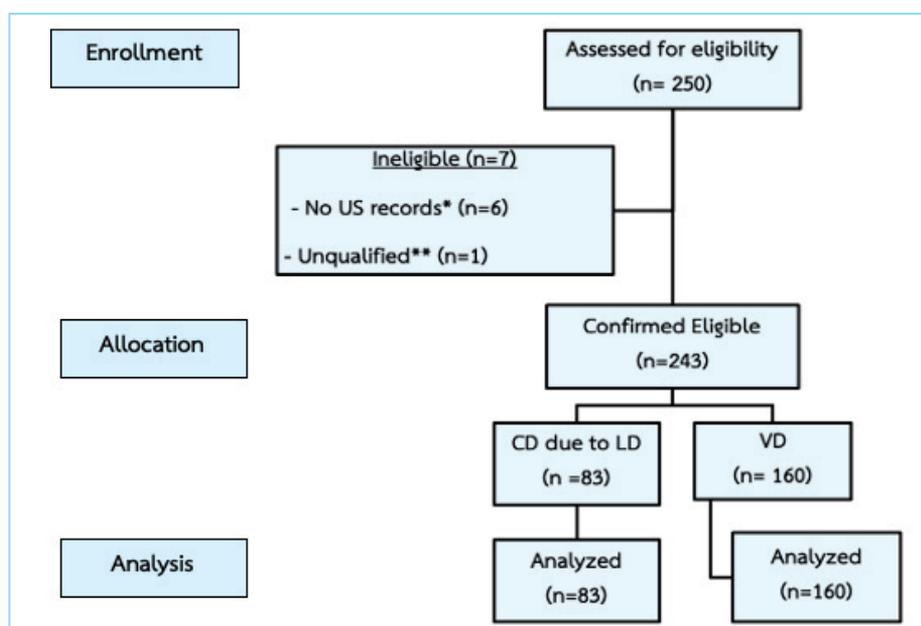


Fig 1. Participant flow diagram.

*No ultrasound records within the week prior to delivery, **Unqualified diagnosis of labor dystocia.

Abbreviations: CD: cesarean delivery, LD: labor dystocia, VD: Vaginal delivery

the parturient and gestational age were 28.6 years and 38.8 weeks, respectively, with no statistically significant differences between groups. Both groups had similar maternal height (MH), total weight gain, and positive gestational diabetes mellitus (GDM) rates. However, the CDLD group had statistically significantly higher pre-pregnancy weight (PPW: 63.5 vs. 58.3 kg), maternal weight at delivery (MWD: 76.3 vs. 70.9 kg), body mass

index at delivery (BMI: 30.5 vs 28.3 kg/m²), and nulliparity (68.7% vs. 41.9%) compared to the VD group.

FBP/MH ratios, including EFW/MH, FHC/MH, FBPD/MH, FAC/MH, and FFL/MH ratios, were significantly higher in the CDLD group compared to the VD group, as shown in Table 1. Additionally, the occiput-posterior position was more frequently found in the CDLD group than in VD group (36.1% vs. 5.6%, p-value < 0.001).

TABLE 1. Baseline characteristics of women included in study and comparison between those who had vaginal delivery (n=160) and those who had caesarean delivery due to labor dystocia (n=83).

	Total*	VD*	CD*	p-value
Age (years)	28.6 ± 5.7	28.4 ± 5.9	28.9 ± 5.4	0.569
Nulliparity**	124 (51.0)	67 (41.9)	57 (68.7)	<0.001
GAB (weeks)	38.8 ± 1.2	38.7 ± 1.1	38.9 ± 1.3	0.218
MH (cm)	158.1 ± 6.7	158.2 ± 6.7	157.95 ± 6.8	0.764
PPW (kg)	60.1 ± 14.1	58.3 ± 13.1	63.5 ± 15.1	0.005
MWD (kg)	72.8 ± 14.8	70.9 ± 14.2	76.3 ± 15.2	0.007
TWG (kg)	12.7 ± 7.6	12.7 ± 8.3	12.7 ± 6.0	0.958
BMI at LR (kg/m ²)	29.1 ± 5.6	28.3 ± 5.5	30.5 ± 5.4	0.004
Positive GDM**	39 (16.1)	23 (14.4)	16 (19.3)	0.536
OP position**	39 (16.0)	9 (5.6)	30 (36.1)	<0.001
Male newborn**	127 (52.3)	81 (50.6)	46 (55.4)	0.478
Birth weight (kg)	3.2 ± 0.4	3.1 ± 0.4	3.4 ± 0.4	<0.001
EFW (kg)	3.1 ± 0.4	3.0 ± 0.3	3.4 ± 0.4	<0.001
FBPD (mm)	91.6 ± 3.9	91.1 ± 4.0	92.6 ± 3.4	0.004
FHC (mm)	326.0 ± 12.1	323.4 ± 11.8	330.9 ± 11.0	<0.001
FAC (mm)	328.5 ± 32.9	323.8 ± 28.6	337.6 ± 38.4	0.002
FFL (mm)	69.9 ± 3.4	69.4 ± 3.2	70.8 ± 3.7	0.003
EFW/MH ratio	19.6 ± 2.5	18.7 ± 2.1	21.3 ± 2.4	<0.001
FHC/MH ratio	2.1 ± 0.2	2.1 ± 0.1	2.1 ± 0.1	<0.001
FBPD/MH ratio	0.6 ± 0.0	0.6 ± 0.0	0.6 ± 0.0	0.013
FAC/MH ratio	2.1 ± 0.2	2.1 ± 0.2	2.1 ± 0.3	0.003
FFL/MH ratio	0.4 ± 0.0	0.4 ± 0.0	0.5 ± 0.0	0.008

*mean ± standard deviation (SD), ** n (%)

Abbreviations: MH : maternal height, BMI : body mass index, GDM : gestational diabetes mellitus, GAB: gestational age at birth, EFW : estimated fetal weight, FBPD : fetal biparietal diameter, FHC : fetal head circumference, FAC : fetal abdominal circumference, FFL : fetal femur length, VD : vaginal delivery, CD : cesarean delivery due to labor dystocia, PPW : pre-pregnancy weight, MWD : maternal weight at delivery, TWG : total weight gain, GDM : gestational diabetes screening, OP : occipito posterior position of fetus

Model development

After multivariable logistic analysis, the influencing factors of labor dystocia, specifically: age, nulliparity, MWD, GDM, EFW/MH ratio, FBPD/MH ratio, FHC/MH ratio, FAC/MH ratio, FFL/MH ratio and fetal position were analyzed to construct the predictive model. The receiver operating characteristic (ROC) curve was generated as shown in Fig 2. Area under the curve (AUC) and p-value were 0.9047. The appropriate cut-off point of the model was 0.23 which provided sensitivity, specificity, LR+, LR-, PPV, and NPV at 91.6, 74.4, 3.57, 0.11, 65, and 94.4 percent, respectively.

Accuracy of predictive model

This model incorporated 10 factors, including age, parity, MWD, FPM/MH ratio (EFW/MH, FHC/MH, FBPD/MH, FAC/MH, FFL/MH ratio), GDM, and fetal position. The probability of the predictive model could be estimated using a combination of 10 factors as illustrated in Table 2. Internal validation was run by the Bootstrap

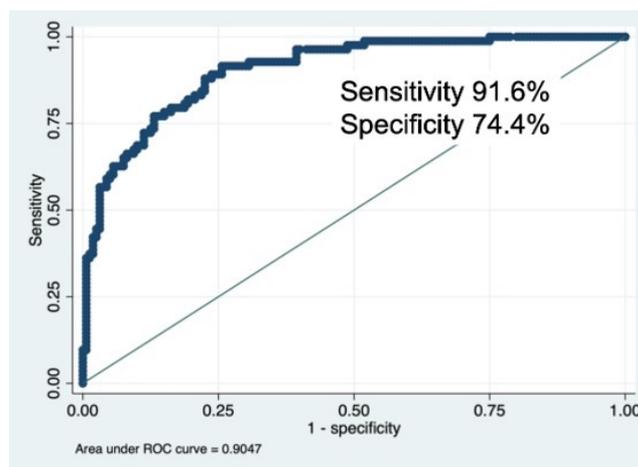


Fig 2. Receiver operating curve (ROC) of Wadeng Score to predict cesarean delivery due to labor dystocia

Abbreviations: PPV: positive predictive value, NPV: negative predictive value, LR+: positive likelihood ratio, and LR-: negative likelihood ratio

TABLE 2. Predictors of cesarean delivery due to labor dystocia in Term pregnancy.

Predictors	coefficient β	OR	95% CI	p-value
Age	0.0760766	1.08	1.00-1.16	0.035
Parity				
Nulli	1.996217	3.04	1.74-5.33	<0.001
Multi	Ref			
MWD	0.0021692	1.02	1.01-1.04	0.009
Ratio				
EFW/MH	0.8940321	1.69	1.45-1.97	<0.001
FBPD/MH	-2.309326	1.59	1.22-2.07	0.001
FHC/MH	0.3593595	2.95	1.23-7.05	0.015
FAC/MH	-0.2086456	1.36	1.13-1.64	0.001
FFL/MH	-1.265261	1.69	1.45-1.97	<0.001
GDM				
Yes	-0.4003198	1.50	0.72-3.13	0.275
No screening	0.7847241	1.18	0.64-2.18	0.598
No	Ref			
Position				
OP	2.42365	9.50	4.23-21.30	<0.001
OA	Ref			

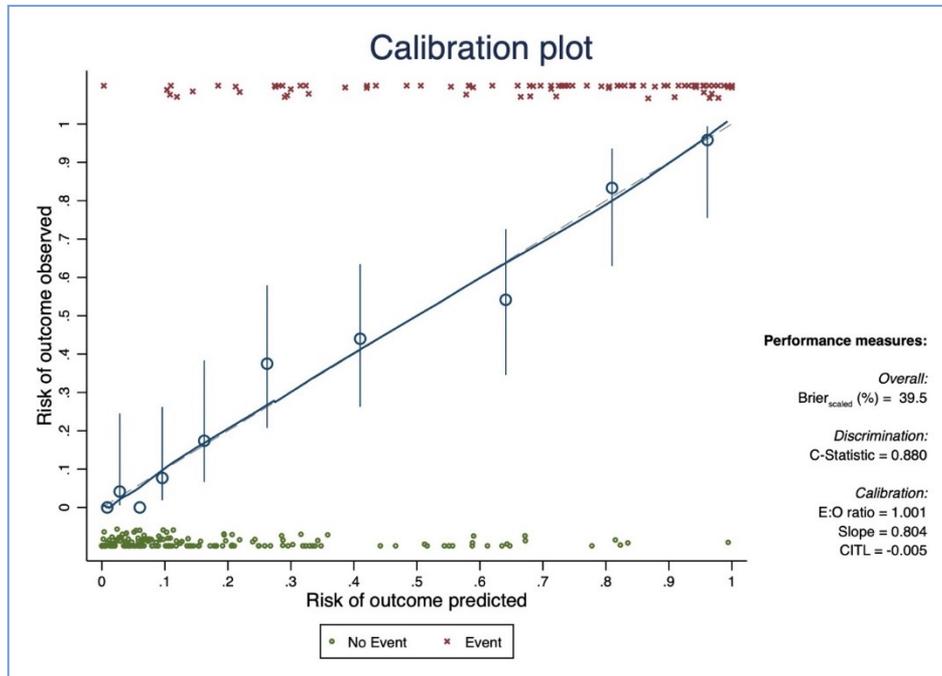
Formula of model : $\exp^z / (1 + \exp^z)$, where $Z = (\text{Age} * 0.0760766) + 1.996217 * (\text{parity: nulliparity} = 1, \text{multiparity} = 0) + 0.0021692 * (\text{MWD}) + 0.8940321 * (\text{EFW/MH ratio}) + (-2.309326 * (\text{FBPD/MH ratio})) + (0.3593595 * \text{FHC/MH ratio}) + (-0.2086456 * \text{FAC/MH ratio}) + (-1.265261 * (\text{FFL/MH ratio})) + (-0.4003198 * \text{GDM: Yes} = 1, \text{No} = 0) + (0.7847241 * \text{No GDM screening: Yes} = 1, \text{No} = 0) + (2.42365 * \text{fetal position: OP} = 1, \text{OA} = 0)$

Abbreviations: MWD : maternal weight at delivery, GAB: gestational age at birth, MH : maternal height, EFW : estimated fetal weight, FBPD : fetal biparietal diameter, FHC : fetal head circumference, FAC : fetal abdominal circumference, FFL : fetal femur length, GDM : gestational diabetes mellitus, OP : occipito posterior position of fetus, OR : odds ratio

method (800 sampling times). The predictive model showed excellent internal validation according to the calibration plot as shown in Fig 3. It represented the agreement of predictive model probability. The decision-curve analysis demonstrated the clinical utility of the model as shown in Fig 4.

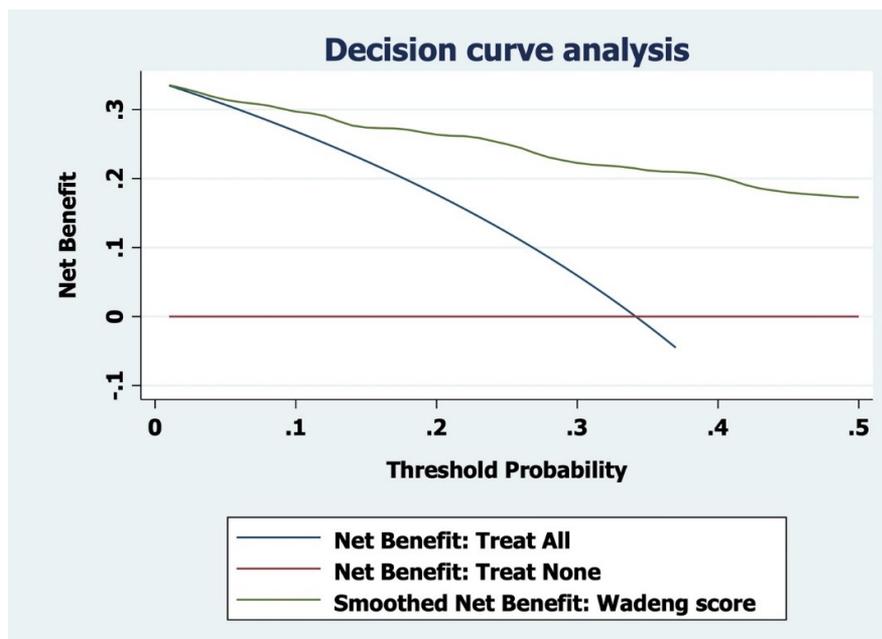
In order to use the model, the clinical setting was divided into three groups, namely: low (<0.32), intermediate

(0.32-0.72) and high risk (>0.72). The score from the prediction model at 0.32 gave the likelihood ratio (LR) for cesarean delivery at 1. However, the score of 0.72 gave LR for cesarean delivery at 10-fold as shown in Fig 5 and Table 4. The enhanced predictive model could be accessed through this web link: <https://wadeng-score.vercel.app/> or QR code as shown in Fig 5.



The result of internal validation was used by the Bootstrap method (800 sampling times). X axis represented the predictive of cesarean delivery by model. Y axis represented the real cesarean delivery. The predictive model showed excellent internal validation according the calibration plot.

Fig 3. Calibration plot of expected and true cesarean delivery prediction



Decision curve for prediction model from 243 parturient in the current study. Line A represented the condition of no treatment and net benefit is zero. Line B represented the condition of treatment for 100 percent of cesarean delivery. Line C represented the effect of treatment according to the presenting model. The presenting model give the expected net benefit than no model used.

Fig 4. Decision curve analysis of the presenting model

TABLE 3. Comparison prediction model for labor dystocia from previous study and our study.

	YunSeok	Yanqing	Present
Years	2022	2023	2024
Country	Korea	China	Thailand
Designs	Retro	Retro	Retro
N	1,326	2,161	243
Stage of labor	Latent and active	Active	Latent
Characteristic			
Age	29.4	26.6	28.9
Nulliparity (%)	31.8	50	51
MH	160.34	No data	158
BMI	26.28	26.39	29.1
CDLD (%)	14.2	8.5	4.47
GA	39.5	42.9	38.8
Factor			
Age	✓		✓
MW			✓
Parity	✓		✓
GA	✓		
GDM			✓
CD	✓		
MS	✓		
PROM		✓	
Oxytocin use	✓		
PLT		✓	
Fetal position		✓	✓
Fetal station		✓	
EFW	✓		
FAC		✓	
EFW/MH			✓
FBPD/MH			✓
FHC/MH			✓
FAC/MH			✓
FFL/MH			✓
ROC	0.859	0.942	0.905
Cutoff	0.1	12.9	0.23
Sensitivity	85.19	84.2	91.6
Specificity	66.58	92.9	74.4
LR+	2.55		3.57
LR-	0.2		0.11

Abbreviations: MW: maternal weight, MH: maternal height, CDLD: primary cesarean rate due to labor dystocia, GA: gestational age, CD: cervical dilatation, MS: meconium staining, PROM: premature rupture of membrane, PLT: prolong latent phase, EFW: estimated fetal weight, FBPD: fetal biparietal diameter, FHC: fetal head circumference, FAC: fetal abdominal circumference, FFL: fetal femur length, PLP: prolong latent phase

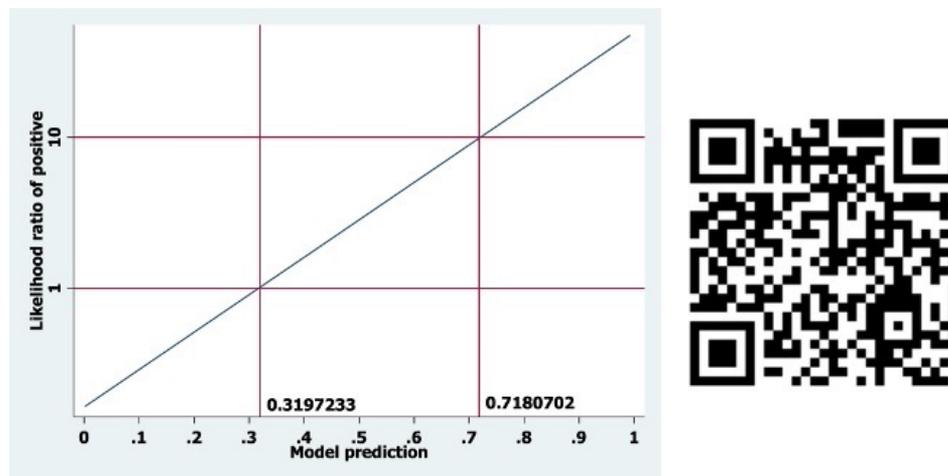


Fig 5. shown likelihood ratio (LR) with predictive score and QR code to access the predictive model using the Wadeng score.

TABLE 4. Distribution of CD due to LD in different level risk categories (low-, intermediate-, and high- risk)

	Score	Prevalence (%)	LR+	95% CI	p-value
Low	<0.32	11.33	0.25	0.16-0.38	<0.001
Intermediate	0.32-0.72	51.11	2.02	1.20-3.39	0.007
High	>0.72	89.58	16.58	6.83-40.30	<0.001

Abbreviations: CD: cesarean delivery, LD: labor dystocia, LR+: positive likelihood ratio, 95%CI: 95% Confidence Interval

DISCUSSION

CD is one of the most common obstetric operations performed worldwide.¹¹ Current estimates indicate that the global cesarean section rate is approximately 21%, with projections suggesting it will rise to 30% by 2030.¹² One of the indications of CD is LD.¹ LD is not currently used as a diagnostic tool. It requires integration of maternal and fetal evaluation, labor progression and expertise of obstetricians attending the patient.^{2,13}

In this study, the correlation between FBP/MH ratio and cesarean delivery due to labor dystocia was evaluated. The FBP/MH ratios: EFW/MH, FBPD/MH, FHC/MH, FAC/MH and FFL/MH were shown as significant independent risk factors for CDLD. Furthermore, a new risk-prediction model named Wadeng score was proposed to estimate the risk of CDLD based on maternal risk factors and fetal sonographic parameters.

Comparison between Previous Model and Our Study

According to Table 3, in 2022 YunSeok presented a prediction model for CDLD. Their model consisted of

parity, GA, MH, cervical dilatation, meconium staining, and the use of oxytocin and estimated fetal weight.¹⁴ The Cesarean rate of YunSeok's study was only 14.2 percent. The AUC of the YunSeok model reported 0.859 levels. A suggested cut point from YunSeok study gave sensitivity, specificity, negative likelihood ratio (LR-) and positive likelihood ratio (LR+) of 85.2 percent, 66.6 percent, 0.2 and 2.5, respectively.¹⁴ Yanqing from China reported their model for CDLD prediction in 2023. The Yanqing model consisted of premature rupture of membranes, FAC, prolonged latent phase, fetal station, and fetal position.¹⁵ The Cesarean rate of Yanqing's study was 8.5 percent. AUC of the Yanqing model reported a level of 0.942. Sensitivity and specificity were reported at 84.2 and 92.9 percent, respectively.¹⁵

The current study incorporated 10 factors including age, parity, MWD, FPM/MH ratio, GDM and fetal position. The predictive model of the current study gave AUC a level of 0.905. Sensitivity, specificity, LR+ and LR- were recorded at 91.6%, 74.4%, 3.57, and 0.11, respectively. The current model gave more sensitivity and LR+ than YunSeok's model (91.6 vs 85.2 percent and 3.57 vs 2.5).

The AUC of current study slightly less than Yanqing's study (0.905 vs 0.942). However, the sensitivity of the current study exceeded Yanqing's report (91.6 vs 84.2 percent) which offers value as a screening tool.

The primary cesarean rates due to labor dystocia in our study, YunSeok's and Yanqing's studies, were 4.47, 14.2, and 8.5 percent, respectively. The possible explanation of low cesarean rates in the current study may be attributed to the strict adherence to ACOG and SMFM diagnostic criteria for labor dystocia by the staff on duty in the delivery room. As a result, cases of labor dystocia were less frequently diagnosed, with most cesarean sections performed for other conditions, such as failed induction.

The predictive value for CDLD from the current study had the same power as YunSeok's and Yanqing's studies. The web-based tool for the health care worker attending the labor room was used for its convenience and ease of use. The application was appropriate for use with parturients in latent phase. Yanqing's was appropriate for use with patients in active phase.¹⁵ YunSeok and Yanqing used EFW and FAC from ultrasonography to generate predictive model, respectively. The Wadeng predictive model used more parameters than YunSeok and Yanqing (EFW/MH, FBPD/MH, FHC/MH, FAC/MH and FFL/MH ratio). The current predictive model was user-friendly for labor-attending personnel in Thailand. Smartphone was electronic device that available in Thailand. It could be the easy screening tool to consider and consult to expertise obstetricians or refer to the well-equipped hospital.

Strengths and weakness

Our study developed an application to ensure convenient access and ease of use for labor attending personnel. This application was suitable for physicians who had limited expertise in assessing LD. Furthermore, the application from the current study categorized patients into three groups, namely: low, intermediate, and high risk for the purposes of management and referral planning. Lack of external validation and single center might be the limitations of the study.

Additional study including multicentric collaboration and larger sample sizes with external validation is suggested for future investigation to assess the predictive model's performance in diverse settings.

CONCLUSION

The Wadeng model was proposed. FBP/MH ratio was an independent risk factor for predicting CDLD.

The Wadeng predictive model could be assessed via internet route by computer devices. Low, intermediate and high risk groupings from the predictive model gave the predictive value of CDLD risk at 0.25, 3.4 and 16.6 folds, respectively. A patient labeled as high-risk from the use of this predictive model might trigger the labor attending personnel to consult an expert obstetrician quite early, or the patient might be referred to a higher tier health center if the current facility has limited resources for future operation requirements. The relatively small sample size and lack of external validation were the limitation of the current study. External validation or integration into clinical practice would be the next step.

Data Availability Statement

Data about individual identified samples of this research will be available from the corresponding author Wanlaya Onwatanasrikul upon reasonable request after the main results of the research have been published.

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DECLARATION

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Conflict of Interest

The authors declare that they have no competing interests in this work.

Registration Number of Clinical Trial

None.

Author Contributions

Conceptualization and methodology, W.W., W.O., N.K., M.P. and S.P.; Investigation, W.W.; Formal analysis, W.W., W.O., N.K., M.P. and S.P.; Visualization and writing – original draft, W.W., W.O., K.B. and K.S.M.; Writing – review and editing, W.W., W.O., M.P., K.B. and K.S.; Supervision, W.O. and K.S. All authors have read and agreed to the final version of the manuscript.

Use of Artificial Intelligence

No content was generated using AI.

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