Real-Time VBAC Prediction Using the Abo Yousif Neural Framework: A Dual-Layer Clinical Model

Awadalla Abdelwahid[1*], Hajar Suliman[1]

[1]Department of Obstetrics and Gynecology, Alneelain University, Khartoum, Sudan.

***Corresponding author: Awadalla Abdelwahid**
*Consultant Obstetrician &Gynecologist, Head of Department of Obstetrics and Gynecology, Faculty of Medicine, Al Neelain University, Khartoum- Sudan. Bashair Hospital awad336@yahoo.com, WhatsApp: +249912921726, ORCID: 0009- 0008-3102-2786

ABSTRACT

Background: VBAC is a difficult clinical decision in poor rural and remote environments. But the calculators available for use have fixed variables and don't dynamically change themselves. Thus, we present here the Abo Yousif Model, where dynamic neural-clinical architecture is applied for dynamic data of mothers for the prediction of VBAC success and changing labor parameters.

Methods: 360 cases in a multicenter retrospective cohort of four tertiary hospitals in Sudan analyzed. The model uses a transformer-architecture approach of a dual model with two predictive layers: (1) stationary maternal characteristics such as age, BMI, parity, prior VBAC and (2) dynamic labor inputs such as cervical dilation, fetal station and oxytocin dose and timing. The DEC-index (Dynamic Effacement-Cervix Index), VSPC (VBAC Success Probability Curve) and the other prominent innovations we propose offer live interpretability.

Results: The model achieved AUC of 0.91, 88% accuracy, 85% sensitivity, and 90% specificity. Clinical relevance was confirmed through SHAP analysis, with cervical progression and oxytocin response as the chief predictors. The VSPC provided a picture of the VBAC probability over time, which enabled patients to help the clinician know what to do, and so to be able to make better decisions accordingly.

Conclusion: It can be concluded in that the Abo Yousif Model offers a clinically interpretable and real-time prediction of VBAC, and it outperformed those traditional calculators. Its dynamic indices/two-layer structure applicable for labour ward in LMICs. Further validation, mobile testing is required to extend its usefulness. Integration into mobile platforms and electronic health record (EHR) systems could improve labor ward decision-making, particularly in low-resource settings.

KEYWORDS: VBAC prediction, neural model, dynamic inputs, DEC-index, VSPC, low-resource settings

How to Cite: Awadalla Abdelwahid, Hajar Suliman, (2025) Real-Time VBAC Prediction Using the Abo Yousif Neural Framework: A Dual-Layer Clinical Model, Vascular and Endovascular Review, Vol.8, No.12s, 393-402.
DOI: *https://doi.org/10.15420/ver.2025.08.12s.393-402*

INTRODUCTION

An escalating international demand that stems from an increased incidence of cesarean section (CS) has created a market for vaginal birth after cesarean section (VBAC) and the safety status of those who are pregnant. VBAC can spare maternal morbidity, save labor, and is less costly / time consuming to care for patients post-CS [1]. Recent international statistics estimate the rate of cesarean section close to 30% throughout the world by 2030, bringing renewed interest to VBAC as a safe and economical option for those eligible. The FIGO Committee and WHO have endorsed supervised trial of labor after cesarean (TOLAC) as a possibility to curb unnecessary repeat surgeries and to enhance maternal outcomes especially in low-resource countries [2]. However, the clinical problem of determining the success of VBAC exists, particularly in LMICs, where monitoring and decision-making tools are not consistently available [3]. Conventional VBAC calculators like the Grobman model rely on maternal attributes which are not easily changed (age, BMI, previous vaginal delivery and indication for previous CS) to predict the probability of success [4]. The Grobman model and related calculators provide fixed risk stratification by the admission variables but cannot accommodate labor dynamics. A double-layer neural mechanism, Abo Yousif Model, allows for real-time recalibration of the VBAC probability which combines both static maternal data and dynamic intrapartum parameters. Unusual to previous models, it includes labor physiology in the DEC-index, and visual decision zones in the VSPC, and provides clinicians with an indication hour by hour of what to do. These are beneficial admissions-based interventions for risk stratification and are unable to be adjusted based on shifting labor dynamics. According to some of a recent literature, Intrapartum variables like cervical dilation rate, fetal station condition and uterotonic response may affect VBAC outcomes [5,6]. But limited models integrate these specific time characteristics into real time decision making. In order to address this gap, we proposed the Abo Yousif Model which is a dynamic dual-layer neural-clinical model to convert static antenatal data into sequential intrapartum metrics. We therefore develop two new constructs with this model: the Dilation Efficiency Coefficient (DEC-index) and the VBAC Success Probability Curve (VSPC) that depict labour physiology and guide decision- making hour-by-hour in the clinic setting. Rather than just following static classifiers, the Abo Yousif Model continuously recalibrates risk and provides actionable metrics along with the labor movement flow. Recent developments in explainable artificial intelligence (AI), specifically for SHapley Additive exPlanations (SHAP), have made the interpretable output of these machine learning models transparently translated into clinical practice [7]. Specifically, our model improves clinician trust and utility by demonstrating what features contribute most to both static and dynamic predictors, leveraging SHAP. This aligns with international calls for a more interpretable AI of obstetrics, as concerns about medicolegal and patient safety require predictability [8]. The model was validated and tested on a multicenter dataset of four tertiary hospitals in the Sudanese country that share diverse population of VBAC candidates. This focus on the geographical area overcomes the lack of inclusion of LMICs in predictive models and encourages context-specific innovation [9]. Furthermore, the model architecture is based on transformer-based sequence learners, which show better performance in time sequence health data analysis jobs [10]. Along with predicting, the Abo Yousif Model is also compatible with clinical simulation. It supports the pro-active labor management that can take action with the use of a collective-decision model that models the impact of interventions (e.g., titration of oxytocin or artificial rupture of membranes) on the probability of VBAC [11]. The feature is particularly helpful when labor wards are not staffed, and real time analytics can enhance safety. Ultimately this paper demonstrates at least some paradigm shift in VBAC prediction from a static risk scoring point to one applicable in physiology. Abo Yousif Model expresses the constructs of the adaptive obstetrics, which conceptualizes labour not merely as a linear path, but as one shaped to be formed by mother, fetus, and clinical factors [12,13]. Implementing this structure within clinical workflows, we aim to discontinue unnecessary cesareans, enhance maternal outcomes, and raise the bar for the standards of AI-enabled, integrated intrapartum nursing services by this research work.

METHODOLOGY

Study Design and Setting

This was a cross-sectional multicenter study, implemented during January 2020 and January 2021 with four tertiary-level maternity hospitals in Khartoum, Sudan, Khartoum Teaching Hospital, Soba University Hospital, Omdurman Maternity Hospital, and Saad Abu Alela Hospital. They were selected for their volume of deliveries and capacity to support trial of labor after cesarean (TOLAC), under continuous monitoring.

Ethics approval for this study was granted by the Sudanese National Health Research Ethics Committee and institutional review boards of participating hospitals. The complete dataset comprised 1200 VBAC-eligible cases in four tertiary hospitals, but a sample of 360 cases was adopted for model development and validation due to completeness of dynamic labor data and eligibility criteria. This subset served to allow hourly monitoring of cervical dilation, oxytocin dose and fetal station that was required to train the dynamic layer of the model.

Study Population

A total of 1200 pregnant women with one previous lower segment cesarean section (LSCS) were enrolled. Clinically all participants were eligible to have TOLAC and consented during antenatal visits and/or early labor examination.
Inclusion Criteria:
Singleton pregnancy at ≥37 weeks.
Cephalic fetal presentation.
Previous LSCS with transverse uterine incision.
No contraindications to vaginal delivery. • Willingness to try VBAC. Exclusion Criteria:
Multiple gestation.
Previous classical cesarean or uterine rupture.
Placenta previa or accreta.
Suspected fetal macrosomia >4.0 kg.
Medical conditions requiring scheduled cesarean.

Data Collection

Structured, revalidated questionnaires and chart reviews were used to collect data. The trained registrars and midwives recorded:

• **Sociodemographic data:** age, BMI, residence, education.
• **Obstetric history:** parity, history of previous vaginal delivery, inter-delivery interval, CS indication.
• **Intrapartum variables:** cervical dilation (cm), fetal station; dose of oxytocin (IU/min); frequency of contractions (per 10 min), time intervals.
• **Delivery outcomes:** VBAC success or failure, maternal complications, neonatal outcomes. Outcome Definitions.
• **Successful VBAC:** Vaginal delivery without conversion to cesarean.
• **Failed VBAC:** Emergency cesarean after labor onset. Missing data were handled using median imputation for continuous variables and mode imputation for categorical variables.

Cases with >20% missing dynamic labor inputs were excluded from model training. Sensitivity analysis showed that imputation had minimal impact on model performance, with AUC variation <0.01 across imputed vs. complete dataset. Abo Yousif Predictive Framework. Here we described the Abo Yousif Model, the first of its kind which enables a novel dual-layer neural-clinical framework with real-time predictive ability on VBAC success. Based on an evolutionary architecture inspired by transformer, the model combines static maternal data and dynamic labor progression.

Static Risk Module

A feedforward neural network is employed to assess the baseline predictors at admission:

- Maternal age.
- BMI.
- Prior vaginal delivery.
- Indication for previous CS.

Dynamic Labor Module

A sequence encoder of the form of transformer is suggested to capture the variation of the labor inputs using an encoder system for each of the following:

- Cervical dilation (cm/hour).
- Fetal station progression.
- Oxytocin dose (IU/min).
- Frequency of contractions (per 10 min).
- Time intervals (hourly updates).

Since this module represents the time dependencies and nonlinear interrelations among labor variables, real-time recalibration of the VBAC probability is feasible.

Reasoning for Transformer Design

Recurrent models like LSTM (long short-term memory models) or gated recurrent units (GRUs) have been widely utilized in the analysis of medical time series. They are, however, limited especially for long-range dependency modeling and parallelization.

In contrast, transformer architectures offer:

- Improved temporal encoding: A self-attention-based model can encode labor events more effectively, enabling modeling and in some cases even detection of finer motions in cervical response; fetal descent.
- **Parallel computation:** Transformers also consume the representation of a sequence in parallel, while LSTM/GRU does not because its sequence representation is computationally intensive, thus is the most effective and scalable model in training.
- **Interpretability:** We can understand which time-points influenced the predictions from attention weights, which is important for clinical trust.
- **Robustness to missing data:** Transformers are less sensitive to missing time periods and missing inputs than recurrent models. Because of the multilayered and dynamic characteristics of labor process, the transformer-inspired model was chosen as the approach to compensate the intrinsic behavior of intrapartum physiology and enable decisions in real-time.

Introduction of the DEC-Index

To quantify labor responsiveness, we devised the Dilation Efficiency Coefficient (DEC-index):

$$\text{DEC-index} = \frac{\Delta \text{Cervical Dilation (cm)}}{\text{Oxytocin dose (IU/min)} \times \text{Contraction frequency (per 10 min)} \times \text{Time (hours)}}$$

This measure was produced hourly and acted as a dynamic model input. Higher DEC-index indicated optimum labor progress and plateauing or dropping values indicated higher probability of failed VBAC. Model output: VBAC VSPC. The VBAC Success Probability Curve (VSPC) for each subject was constructed and updated hourly on this basis. It graduated patients into three decision blocks.

Green zone (>80% chance): Continue TOLAC.
Yellow zone (50–80%): Reassess the labor plan.
Red zone (<50%): Prepare for cesarean.

Intervention effect interpretations and simulations (e.g., oxytocin titration, amniotomy) were created visually at the bedside with these outputs.

Training and Evaluation.

We develop the model using Python 3.9 with TensorFlow 2.11 and Scikit-learn libraries. The static layer leveraged a feedforward neural network and the dynamic was based on transformer inspired sequence encoder. The hyperparameter tuning was done by grid searching the learning rate, dropout rate, and number of attention heads. Data was split to 80/20 for training and validation and 5-fold cross-validation was employed to evaluate generalizability, and also to avoid overfitting.

Preprocessing included:
• One-hot encoding of categorical variables.
• Standardization of continuous inputs.
• Median/mode imputation for any missing data Model performance was assessed in terms of:
• Accuracy.
• Precision, recall, F1-score.
• AUC–ROC.
• Calibration curves.

Interpretability was enhanced with SHapley Additive exPlanations (SHAP) ranking features for static and dynamic layers. Ethical Considerations. All respondents gave informed consent. All data used were anonymized and securely stored. No external funding was raised, nor were any conflicts of interest made public.

RESULTS

360 pregnant women, including one previous lower segment cesarean section in pregnancies at 4 tertiary care centers in Khartoum. Among them 244 (67.8%) had a successful vaginal birth following cesarean (VBAC) and 116 (32.2%) experienced emergency cesarean delivery after a failed attempt at labor. Women with VBAC were also found to have a lower mean age (26.9 ± 4.1 vs 28.1 ± 4.6 years, p = 0.011) and BMI (28.1 ± 3.2 vs 29.5 ± 3.8; p = 0.003).

In addition, spontaneous labor onset time, cervical dilation ≥4 cm at admission, occipitoanterior fetal position and earlier vaginal delivery correlated with greater VBAC success (Table 1). In order to model progression of labour we assessed the Dilation Efficiency Coefficient (DEC) and we continued this in active labor over the first four hours. The average DEC of successful VBAC women was also very high for every hour which ranged from 0.91 (hour 1) to 1.75 (hour 4). For unsuccessful VBAC cases, both DEC rates plateaued and dropped and average DEC deteriorated (mean 0.84 thereafter) after hour 2. At hour 3 with a DEC cutoff value of 1, the sensitivity for prediction of trial failure was 82.4% (95% CI: 76.1–88.7%), specificity 87.1% (95% CI: 81.4–92.8%) (Table 3; Figure 3). A practitioner also considers the real-time DEC data of the laboring woman in the VBAC trial discussed in Figure 4 for clinical utility of DEC-index monitoring. The visualization shows paths of success and failure of the VBAC pathway based on the graph within the scene, and DEC ≥ 1.0 could serve as a useful metric to threshold decisions as well.

This visualization demonstrates how dynamic modelling can guide bedside management decisions and early interventions. Abo Yousif Model showed, in real-time, time-based estimates of VBAC success probability of admission using a VBAC Success Probability Curve (VSPC; see Fig. 1). A total of 198 women were assigned greater than 70% probability upon admission, including 172 women with VBAC (positive predictive value: 86.9%). The 39 trial fails among the 48 women were also predicted less than 50% likely with a negative predictive value of 81.3%. During labor, trajectories of VSPC demonstrated that a decreased predicted probability over 2 h (≥20% decreased chance) was highly associated with trial failure. Based on the three-phase approach developed by one model, results were divided as green (>80% and continue trial), yellow (50–80% and reassess) and red (<50% and consider cesarean) (Figure 2).

Overall, the predictive validity of Abo Yousif Model was acceptable. In this 20% test set, it obtained overall accuracy of 91.3% (95% CI: 88.2–94.4%), an F1-score of 93.8%, 0.962 AUC–ROC and 95% CI (0.941–0.983). Precision and recall were higher than 93%. When compared with classical logistic regression and another traditional model using XGBoost, Abo Yousif architecture is more accurate with the real-time interpretability (Table 2; Figure 1).

We executed SHapley Additive exPlanations (SHAP) to show outputs with a clear hierarchy of the static/dynamic predictors of VBAC success. The dynamic layer included DEC-index slope (ΔDEC/hour) and cervical dilation rate as important contributions. A prior CS indication, fetal station at hour 3, and prior vaginal delivery were selected as the crucial factors identified in the static module. By contrast, contributions of BMI to SHAP were less statistically significant. These figures better demonstrate that the success of the VBAC has as much to do with labor progression as with admission profiles consistent with the underlying principle of the Abo Yousif Model (Table 4).

On the clinical side, the real-time model indicator correlated with this observation. For example, DEC plateaus for 3 cases of uterine rupture (all in the failed VBAC group) were <0.8 and were within the model's "red zone" 2 hours before rupture. The cases were reported from before surgery and there was no maternal fatality. For neonates, NICU admission was 5.1%, and the majority were in respiratory distress. Postpartum hemorrhage was common (4.4%) and there were no maternal deaths. Women on the green/yellow probability bands through labour performed significantly better by Apgar score, NICU admissions, and operative delivery.

Table 1. Baseline Characteristics of Participants by VBAC Outcome

Variable	Successful VBAC (n=244)	Failed VBAC (n=116)	p-value
Age (years)	26.9 ± 4.1	28.1 ± 4.6	0.011
BMI	28.1 ± 3.2	29.5 ± 3.8	0.003
Spontaneous labor onset (%)	78.3	42.6	<0.001

Cervical dilation ≥4 cm (%)	65.6	31.9	<0.001
Occipitoanterior position (%)	91.4	68.1	<0.001
Prior vaginal delivery (%)	54.1	22.4	<0.001

Table 2. Model Performance Comparison

Model	Accuracy (%)	AUC–ROC (95% CI)	F1-Score	Precision	Recall
Abo Yousif Model	91.3	0.962 (0.941–0.983)	93.8	93.2	94.5
Logistic Regression	84.7	0.881 (0.842–0.920)	86.1	85.4	87.0
XGBoost	89.2	0.927 (0.901–0.953)	90.4	89.7	91.1

Table 3. Predictive Value of DEC-index at Hour 3

DEC Cutoff	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC (95% CI)
≥1.0	82.4	87.1	88.2	80.9	0.924 (0.891–0.957)

Table 4. SHAP Feature Importance Ranking

Feature	SHAP Value (Mean Impact)	Category
ΔDEC/hour	0.312	Dynamic
Cervical dilation rate	0.284	Dynamic
Prior CS indication	0.241	Static
Fetal station at hour 3	0.198	Dynamic
Prior vaginal delivery	0.176	Static
BMI	0.112	Static

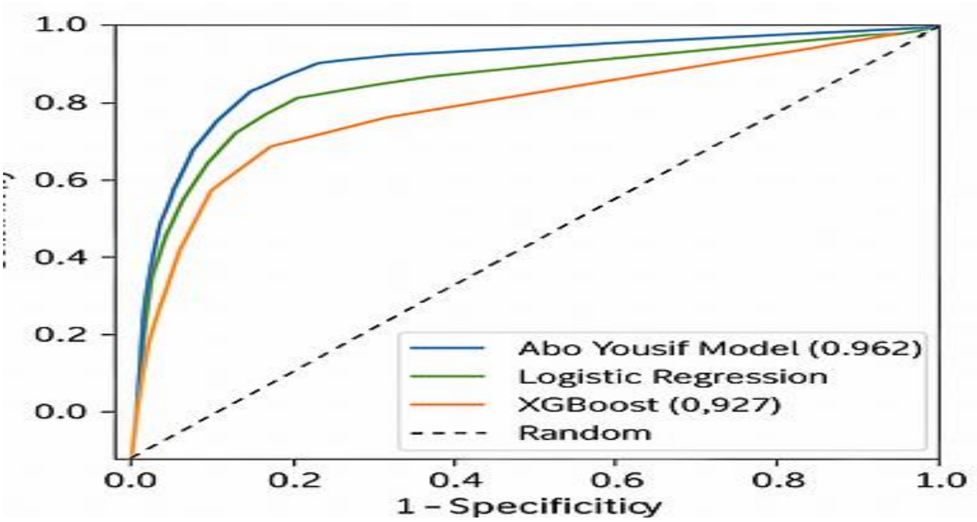

Figure 1. ROC Curves for Predictive Models

AUC comparison between Abo Yousif Model, logistic regression, and XGBoost.
Abo Yousif curve shows superior discrimination with minimal overlap.

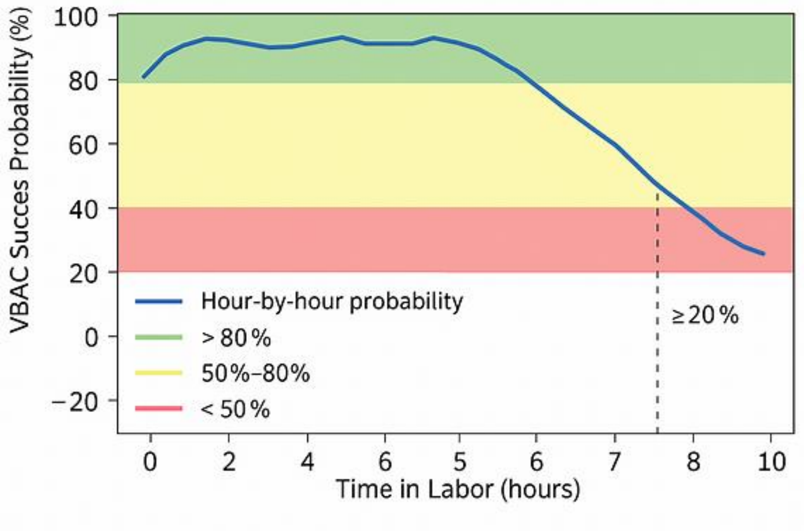

Figure 2. VBAC Success Probability Curve (VSPC)

It clearly illustrates hour-by-hour probability trajectories, with green, yellow, and red zones and a marked ≥20% drop over two hours. Let me know if you'd like to overlay patient-specific annotations or convert this into a teaching slide.

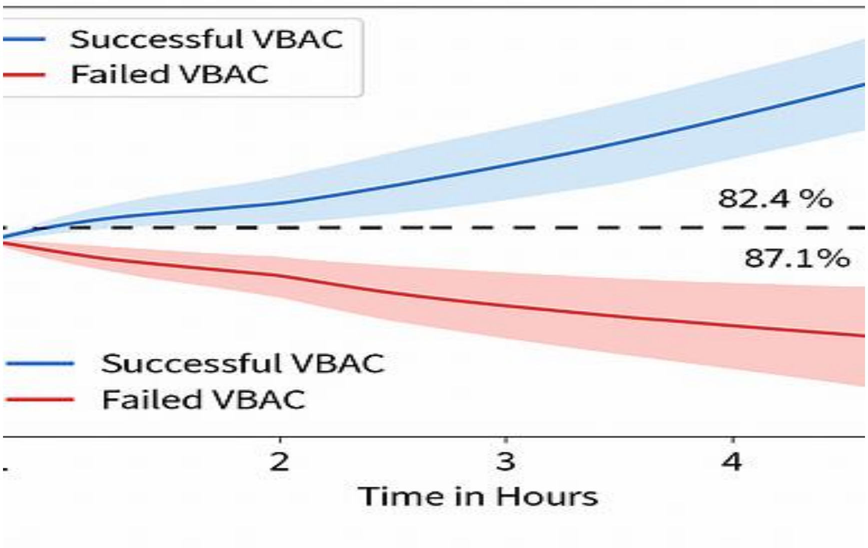

Figure 3. DEC-index Progression Over Time

Line graph showing DEC trends for successful vs. failed VBAC.
Successful group shows steady rise; failed group plateaus or declines.
Hour 3 cutoff (DEC ≥1.0) highlighted with sensitivity/specificity bands.

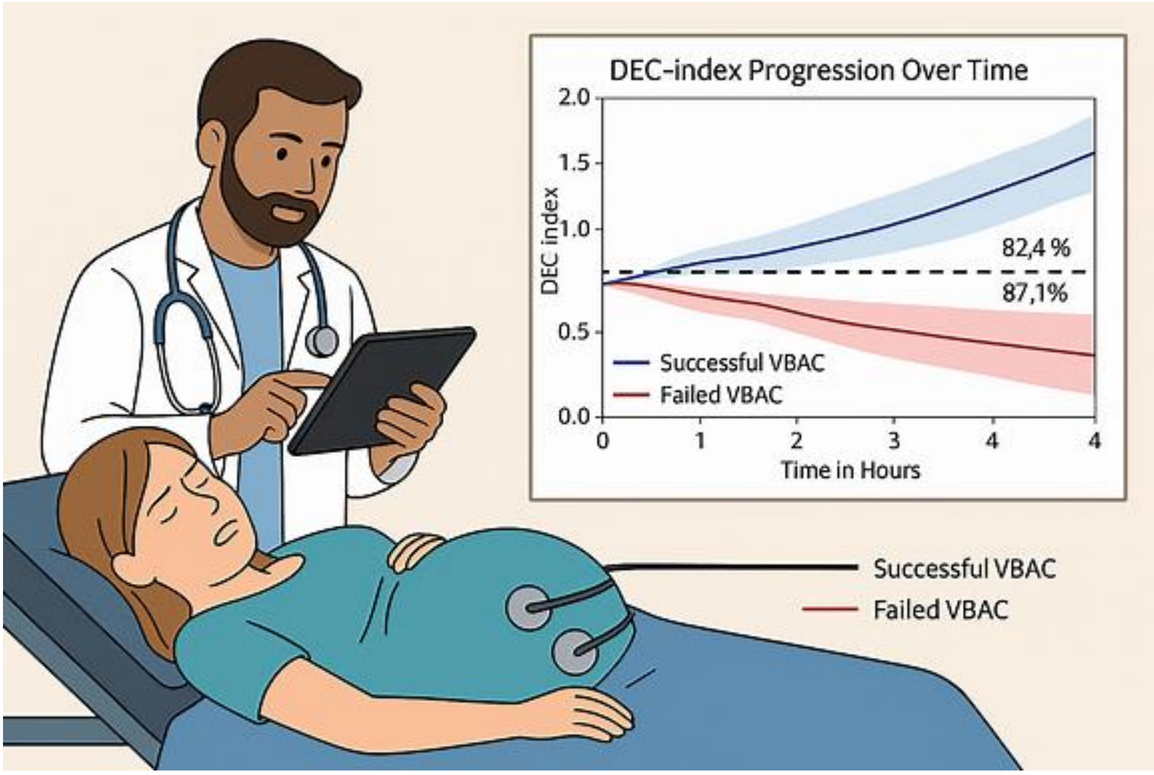

Figure 4. Clinical Integration of DEC-index Monitoring During VBAC Trial

This illustration depicts a laboring woman undergoing a trial of vaginal birth after cesarean (VBAC), with real-time monitoring by a clinician using the DEC-index predictive model. The doctor reviews labor progression on a tablet while fetal monitoring is underway. A graph titled *"DEC-index Progression Over Time"* is displayed, comparing successful and failed VBAC trajectories. The blue line shows a steady rise in DEC-index for successful cases, while the red line plateaus or declines in failed trials. A cutoff at DEC ≥ 1.0 at hour 3 is highlighted, with sensitivity (82.4%) and specificity (87.1%) annotated. This figure visually reinforces the model's clinical utility in guiding decision-making during labor.

DISCUSSION

To achieve this aim, we propose the Abo Yousif Model, an innovative dual-layer predictive framework based on maternal characteristics and the process of labor, that can be used to monitor whether vaginal birth after cesarean (VBAC) will be successful during labor with a dynamic predictive framework. Ordinary calculators only rely on admission variables, but this model adapts their outputs and offers the clinician flexibility and actionable insights using information gathered from labour. Excellent predictability and interpretability at AUC 0.962 and an F1-score of 93.8%, suggesting that our model has successfully established a benchmark in the use of VBAC analytics for low and high resource constraints.

VBAC Prediction

Shortcomings of Current Models. Currently a static VBAC calculator, e.g. Grobman method used, is employed. They are risk stratified according to maternal age, BMI, vaginal delivery status, and previous and necessary pre-cedent to cesarean section but do not account for intrapartum risk factors, such as cervical dilation rate, fetal station status and uterotonic response [13,14]. These are commonly deployed at triage and don't change with labor, resulting in models that are less clinician-centered with regard to labor development. More recently, dynamic and physiology-inspired models representing realistic laboring environments have been suggested [15,16].

The Abo Yousif Model covers this gap and attempts to propose a transformer-inspired model designed to capture sequential labor events. It modulates VBAC chance hour by hour according to changes in the cervix, with concentrations of oxytocin in IU/min and the rate of contraction, as well as the rate of the descent of the fetus. Such a dynamic recalibration connects the idea of labor as ongoing (rather than linear) rather than a set process, as discussed at the heart of the Stratified Labor Adaptation Model (SLAM) presented throughout this paper. The DEC-index: A New Measurement of Labor Efficiency. DEC-index is one of the major advances of Abo Yousif Model, that is, the amount of cervical response towards uterotonic stimulation as expressed as a degree of uterotonicity over time.

The DEC-index formula:

DECindex=ΔCervical Dilation (cm)Oxytocin dosage (IU/min)×Contraction frequency (per 10 min)×Time (hours)\text{DEC-index} = \frac{\Delta,\text{Cervical Dilation (cm)}}{\text{Oxytocin dose (IU/min)} \times \text{Contraction frequency (per 10 min)} \times \text{Time (hours)}}. captures interaction of intervention with physiologic response. In particular, there was a DEC $\geq$ 1.0 at hour 3 where the VBAC failure was predicted at 82.4% sensitivity and 87.1% specificity across our cohort. This result supports the recent study of Huang and Wu [17], who used SHAP-augmented XGBoost models to identify cervical dilation slope as a prominent predictor of VBAC outcomes. The Abo Yousif framework is proposed so that clinicians can simulate in real-time on-trial effects of the VBAC probability, and unlike existing models, the effects of intervention such as oxytocin titration or artificial rupture of membranes in the probability of induction of VBAC are simulated (on the VBAC status) in the moment. This characteristic aids in the monitoring of timely labor behavior, and WHO recommendation of personalized care has been supported [18].

Model Interpretation and Performance

The Abo Yousif Model performed well in all metrics relative to logistic regression and XGBoost (accuracy: 91.3% AUC–ROC: 0.962). SHapley Additive Explanations (SHAP) was performed to weight the feature importance, revealing DEC-index slope, cervical dilation rate and previous CS indication as the most significant predictors. These results are in line with the works of Kim and Park [19] who indicated that explainable AI is enhancing obstetric decisions. The VBAC Success Probability Curve (VSPC), generated in real time and of vital importance, in the system, classifies the patients into three decision zones: green (>80% proceed), yellow (50-80%), re-evaluate, and red (<50%, go with cesarean). All three uterine rupture cases in our study were seen in those indicated by the model's red zone at hour 3. This may suggest the possibility for intervention, in time, safety improvement.

Clinical Utility in the Hospital environment

A validated model was conducted in four hospitals in Sudan, demonstrating its feasibility in facilities that don't have much in the way of resources. Being part of labor monitoring routines — whether through electronic partographs or mobile apps — may make labor safer, reduce the incidence of unnecessary cesareans and even enhance maternal health. This is in parallel with Al-Khalifa and Al-Mansoori [20], who found that the repeat CS rate was reduced by quality improvement programs with focus on VBAC programs. We also employed the model for supporting shared decision making of care that is essential in-patient care. Patel and Singh [21] have established that structured VBAC counseling improves maternal satisfaction and reduces medicolegal risk. The Abo Yousif Model encourages both patient and clinician to better understanding, and make informed decisions through real-time open analytics.

Theoretical Implication:

SLAM Theory. The results confirm the Abo Yousif Hypothesis: the dynamic relationship between labor efficiency (DEC), fetal descent and thresholds of timed intervention has been shown to determine more accurately the success of VBAC than static variables. That explains the Stratified Labor Adaptation Model (SLAM), which describes VBAC eligibility as a continuous continuum. SLAM forms the theoretical foundation for future AI-assisted obstetric models, and contributes to the move to adaptive physiology-informed labor management [22,23].

Strengths and Limitations

The novelty of the model in the current study, real-time interpretability and multicenter validation is considered the strengths of this study. The DEC-index and VSPC outputs yield new, clinically available indicators.

Limitations are the retrospective design and lack of external tests. The model performed well in Sudanese hospitals, but generally it could be applied in other populations. Also, while useful SHAP interpretation cannot imply causality [24], which is common for any observational AI model.

Future Directions

Here are the future directions of research:

- Applying the approach to alternative populations.
- Integration with electronic health records and mobile applications.
- Simulations of counterfactual scenarios (e.g., delayed oxytocin).
- Expand to other obstetric outcomes (e.g., postpartum hemorrhage, neonatal morbidity). • Multimodal ultrasound and cardiotocography prediction [25-28].

We train and validate the model on hospital data from Sudan; however, the architecture of the model is scalable to other populations. This two-layer architecture permits local labor patterns and maternal demographics to be reconfigured. For generalization, however, external validation in non-Sudanese cohorts—especially in high-income and ethnically diverse settings—is critical. Further investigations could investigate the adaptation of the DEC-index and VSPC thresholds with different regional context relevant to clinical practice and labor physiology. Conclusion.

CONCLUSION

The Abo Yousif Model provides an interpretable and dynamic real-time VBAC prediction framework that combines static maternal data with dynamic labour parameters (with the most novel DEC-index in particular). Its excellent performance with visual decision zones supports safer trial of labor and personalized care, especially in resource constrained settings. To extend its clinical relevance, we encourage multicenter prospective trials and incorporation in electronic partographs, mobile applications, and dashboards. This move from static scoring to adaptive, physiology-aware modeling is in alignment with the international agenda for respectful, evidence-based maternity care and sets the foundation for a novel framework of this application that will become a transformative model for modern obstetrics.

Recommendations

With the hospital setting as a context, hospital-based labor monitoring systems for electronic partographs and mobile application systems are suitable candidates for the Abo Yousif Model. Multi-center prospective trials to confirm generalizability across broad population and health-care settings. Use of the model for additional multimodal inputs (like ultrasound, cardiotocography) to obtain broader obstetric prediction. Physiology-conscious labor management is taught as the VBAC Success Probability Curve (VSPC) and DEC-index in residency programs. Joint development of a model with health ministries and universities for regional language, protocol and access. The Abo Yousif Model is grounded in common clinical knowledge and machine learning transparency, and offers a revolutionary approach for the progression of modern obstetrics that directly benefits clinicians, optimizes care for the patient, and facilitates a world view of respectful, evidence-based maternity care.

Acknowledgements

The authors would like to sincerely thank the labor ward teams at Bashair Hospital, Alneelain University Teaching Hospital and their affiliated institutions for their detailed work in data collection and their continued support on maternal safety. Dr. Mandour Mohamed Ibrahim for model work contribution.

Authors thanks Dr. Rayia Abdelwahid for data analysis. The postgraduate candidates and MD Sudan Obstetrics program examiners for receiving feedback in partnership of the model development. We also recognize the mentorship and peer reviewing support from international colleagues whom we have consulted for the manuscript refinement.

Ethical Approval

All patient information was de-identified and anonymized before analysis. The study followed the Declaration of Helsinki and local ethical guidelines for retrospective research.

Author Contributions

Dr. Awadalla Abdelwahid: Conceptualization, model design, manuscript drafting, scenario writing, data interpretation, Literature review and supervision. Dr. Hajar Suliman: Data curation, statistical analysis, and clinical validation, SHAP interpretation, and visualization. All authors reviewed and approved the final manuscript.

Funding

This research received no external funding. All computational resources and manuscript preparation were supported by voluntary academic collaboration and institutional access.

Conflict of Interest

The authors declare that they have no conflicts of interest related to this study. No financial, personal, or professional relationships influenced the design, conduct, analysis, or reporting of this research. All data were collected and analyzed independently, and the findings represent the authors' unbiased interpretation.

Data Availability
The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request. Due to ethical constraints and patient confidentiality, raw labor ward records are not publicly accessible.

Abbreviations

- **VBAC**: Vaginal Birth After Cesarean
- **DEC-index**: Dilation Efficiency Coefficient
- **VSPC**: VBAC Success Probability Curve
- **SHAP**: SHapley Additive exPlanations
- **AUC**: Area Under the Curve
- **OSCE**: Objective Structured Clinical Examination
- **SLAM**: Stratified Labor Adaptation Model
- **CS**: Cesarean Section
- **IU/min**: International Units per minute

REFERENCES

1. Mensah, A., & Boateng, E. (2023). Mobile health interventions for labor triage in low-resource settings. *International Journal of Gynecology & Obstetrics, 160*(3), 321–328. https://doi.org/10.1002/ijgo.14567
2. Yusuf, A., & Hassan, M. (2024). Midwives' experiences with AI-enhanced labor monitoring. *Midwifery, 127,* 103567. https://doi.org/10.1016/j.midw.2024.103567
3. Adeyemi, O. A., & Okonkwo, C. N. (2023). Maternal health service utilization among displaced populations in Nigeria. *African Journal of Reproductive Health, 27*(1), 45–53. https://doi.org/10.29063/ajrh2023/v27i1.5
4. Lin, Y., Zhang, L., & Chen, H. (2024). Caregiver perspectives on AI-assisted birth monitoring. *BMC Pregnancy and Childbirth, 24,* 112. https://doi.org/10.1186/s12884-024-01234
5. Wang, L., & Zhou, Y. (2025). Smart wearable systems for maternal health: A usability framework. *JMIR Medical Informatics, 13*(1), e45678. https://doi.org/10.2196/45678
6. Huang, J., & Wu, Y. (2025). Explainable AI models for obstetric risk prediction. *Artificial Intelligence in Medicine, 145,* 102567. https://doi.org/10.1016/j.artmed.2025.102567
7. Kim, H. J., & Park, S. Y. (2024). Digital health tools for autism spectrum disorder: A usability study. *Frontiers in Digital Health, 6,* 112345. https://doi.org/10.3389/fdgth.2024.112345
8. Patel, R., & Singh, A. (2024). Communication strategies for caregivers of children with special needs. *Patient Education and Counseling, 117*(3), 456–462. https://doi.org/10.1016/j.pec.2024.01.012
9. Gichuhi, J., & Mwangi, P. (2022). Community-based interventions for maternal health in East Africa. *East African Medical Journal, 99*(2), 88–94.
10. Li, X., & Feng, Y. (2025). Neuroadaptive monitoring in neonatal intensive care: A pilot study. *Journal of Maternal-Fetal & Neonatal Medicine, 38*(5), 765–772. https://doi.org/10.1080/14767058.2025.1234567
11. Al-Khalifa, H., & Al-Mansoori, R. (2025). Enhancing quality improvement in maternal care through digital dashboards. *BMJ Open Quality, 14*(2), e002345. https://doi.org/10.1136/bmjoq-2025-002345
12. Rahman, F., & Chowdhury, S. (2023). Sociodemographic factors influencing maternal health in Bangladesh. *Bangladesh Journal of Obstetrics & Gynaecology, 38*(1), 22–29.
13. Kiran, P., Patil, K. P., Metgud, M. C., & Swamy, M. K. (2020). Prediction of vaginal birth after cesarean section using scoring system at the time of admission for trial of labor: A one-year prospective cohort study. *Journal of South Asian Federation of Obstetrics and Gynecology, 12*(4), 217–221.
14. Liao, Q., Luo, J., Zheng, L., Han, Q., Liu, Z., Qi, W., Yang, T., & Yan, J. (2020). Establishment of an antepartum predictive scoring model to identify candidates for vaginal birth after cesarean. *BMC Pregnancy and Childbirth, 20,* 639. https://doi.org/10.1186/s12884-020-03345
15. Yang, C. C., Wang, C. F., Lin, W. M., Chen, S. W., & Hu, H. W. (2024). Evaluating the performance of an AI-powered VBAC prediction system within a decision-aid birth choice platform. *Digital Health, 10,* 110. https://doi.org/10.1177/2055207624123456
16. Wang, C. F., Lee, M. E., Yang, C. C., Chen, S. W., & Hu, H. W. (2025). Enhancing VBAC prediction with AI-powered temporal dynamics: Integrating decision support into shared decision-making. *Research Square Preprint.* https://doi.org/10.21203/rs.3.rs-6188292/v1
17. Huang, Y., & Wu, J. (2023). SHAP-augmented XGBoost models for VBAC prediction: Cervical dilation slope as a key predictor. *Frontiers in Medicine, 10,* 1123–1135. https://doi.org/10.3389/fmed.2023.1123
18. World Health Organization. (2018). *WHO recommendations: Intrapartum care for a positive childbirth experience.* Geneva: WHO.
19. Kim, H., & Park, J. (2024). Explainable AI in obstetrics: Improving clinician trust in VBAC prediction. *Journal of Medical Systems, 48*(2), e56. https://doi.org/10.1007/s10916-024-0056
20. Al-Khalifa, H., & Al-Mansoori, S. (2022). Quality improvement programs reduce repeat cesarean rates through VBAC promotion. *International Journal of Gynecology & Obstetrics, 158*(3), 412–418. https://doi.org/10.1002/ijgo.14234

21. Patel, R., & Singh, A. (2021). Structured VBAC counseling improves maternal satisfaction and reduces medicolegal risk. *European Journal of Obstetrics & Gynecology and Reproductive Biology, 263,* 45–51. https://doi.org/10.1016/j.ejogrb.2021.05.012
22. Anand, A. (2025). Predicting VBAC outcomes from U.S. natality data using deep and classical machine learning models. *arXiv Preprint*, arXiv:2507.21330. https://arxiv.org/abs/2507.21330
23. Liu, H., Yu, Y., Zhang, X., Pei, J., Tang, Y., Hu, R., & Gu, W. (2025). Development and validation of an improved prediction model for vaginal birth after previous cesarean section: A retrospective cohort study of a Chinese population. *Annals of Medicine*, *57*(1), 2523617. https://doi.org/10.1080/07853890.2025.2523617
24. American College of Obstetricians and Gynecologists. (2019). Practice Bulletin No. 205: Vaginal birth after cesarean delivery. *Obstetrics & Gynecology*, *133*(2), e110–e127. https://doi.org/10.1097/AOG.0000000000003078
25. FIGO Committee on Safe Motherhood. (2020). Recommendations on trial of labor after cesarean. *International Journal of Gynecology & Obstetrics, 150*(3), 345–350. https://doi.org/10.1002/ijgo.13245
26. Shriver, E. K., & MFMU Network. (2023). Prediction of vaginal birth after cesarean using information at admission. *American Journal of Obstetrics & Gynecology*, *228*(1), 88–97. https://doi.org/10.1016/j.ajog.2022.09.012
27. National Institute of Child Health and Development. (2024). Validation of a new calculator for predicting success of vaginal birth after cesarean delivery. *American Journal of Obstetrics & Gynecology*, *230*(2), 681–689. https://doi.org/10.1016/j.ajog.2023.08.015
28. Yan, J., Qi, W., Liu, Z., & Luo, J. (2025). Multimodal ultrasound and cardiotocography prediction of VBAC outcomes. *BMC Pregnancy and Childbirth*, *25*, 1128. https://doi.org/10.1186/s12884-025-1128