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**AI-Driven Prediction of Preterm Birth via Uterine
Bioelectrical Signal Analysis (EHG) towards Personalized
Tocolysis Management**

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Abstract

Preterm birth remains a leading cause of neonatal morbidity and mortality worldwide, affecting approximately 15 million infants annually. Current diagnostic methods, including tocodynamometry and cervical length assessment, exhibit limited predictive accuracy and fail to provide personalized risk stratification. Electrohysterography (EHG), which non-invasively records uterine myoelectrical activity, offers a superior alternative with higher sensitivity and robustness. This congress paper synthesizes recent advances in artificial intelligence-driven EHG signal analysis for preterm birth prediction. Machine learning and deep learning architectures, including multi-head attention networks, multivariate empirical mode decomposition, and hybrid deep learning frameworks, have achieved classification accuracies exceeding 96%, with sensitivities up to 98.5%. Beyond prediction, EHG-based AI models enable dynamic monitoring of tocolytic therapy response, facilitating personalized tocolysis management through real-time assessment of uterine contractility patterns. Despite promising results, challenges persist, including dataset imbalance, lack of external validation, and absence of standardized protocols. This review establishes an integrated framework linking EHG signal processing, AI-based prediction, and personalized clinical decision-making, and outlines future directions toward precision obstetrics.



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1. Introduction

Preterm birth (PTB), defined as delivery before 37 completed weeks of gestation, constitutes a major global health challenge, accounting for approximately 15 million cases annually and representing the leading cause of neonatal mortality among children under five years of age (Chopra et al, 2026; Williams, 2025). The global PTB rate ranges from 5% to 10% in developed nations, with significantly higher prevalence in resource-limited settings (Novillo-Del Álamo et al, 2026). Survivors of preterm delivery face elevated risks of respiratory distress syndrome, neurodevelopmental impairments, and long-term cardiovascular and metabolic disorders, imposing substantial burdens on healthcare systems and families (Barnova et al, 2025). Current clinical methods for PTB risk assessment, including cervical length measurement via transvaginal ultrasound, fetal fibronectin testing, and tocodynamometry (TOCO), demonstrate limited predictive accuracy and are often unable to distinguish true preterm labor from false alarms (Chowdhury et al, 2026; Barnova et al, 2025). TOCO, the most widely used technique, measures abdominal pressure changes but is significantly affected by maternal obesity, movement, and suboptimal sensor placement, compromising its reliability (Barnova et al, 2025). Invasive intrauterine pressure catheterization, while more accurate, carries risks of infection and placental abruption, limiting its routine use. Electrohysterography (EHG) has emerged as a promising non-invasive alternative that records uterine myoelectrical activity via surface electrodes placed on the maternal abdomen (Barnova et al, 2025). EHG signals reflect myometrial action potentials propagating through gap junctions, providing detailed information about uterine contractility from as early as the 19th week of gestation (Cholke et al, 2025; Barnova et al, 2025). The integration of artificial intelligence (AI) with EHG signal analysis has opened new frontiers in preterm birth prediction and personalized clinical management. This paper provides a comprehensive review of AI-driven EHG-based approaches for PTB prediction and their translation toward personalized tocolysis management.

2. Electrohysterography: Principles and Advantages

EHG records the bioelectrical activity of uterine smooth muscle cells, capturing the propagation of action potentials that precede and accompany mechanical contractions. The EHG signal comprises two primary components: a low-frequency slow wave (0.01-0.03 Hz) and a fast wave burst (0.3-3 Hz) corresponding to action potential bursts associated with contractions (Barnova et al, 2025). Standard EHG acquisition employs four bipolar electrodes arranged in a rectangular configuration on the maternal abdomen, with signal preprocessing typically involving bandpass filtering within 0.1-4 Hz (Chowdhury et al, 2026). Compared to conventional methods, EHG offers several distinct advantages: (1) direct measurement of uterine electrical activity rather than indirect pressure estimation; (2) higher signal-to-noise ratio and robustness against maternal movement and obesity; (3) ability to detect subtle changes in uterine contractility before mechanical manifestations; and (4) suitability for continuous, long-term monitoring in both inpatient and outpatient settings (Barnova et al, 2025; Cholke et al, 2025). The US Food and Drug Administration has recognized EHG as a preferred alternative for



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women with elevated body mass index, where TOCO accuracy is significantly compromised (García-Casado et al, 2025).

3. AI-Driven Prediction of Preterm Birth from EHG Signals

3.1 Signal Processing and Feature Extraction

The translation of raw EHG signals into clinically actionable predictions requires sophisticated signal processing and feature extraction. Time-domain features (amplitude, duration, contraction frequency), frequency-domain features (power spectral density, median frequency), and non-linear features (entropy, complexity, synchronization indices) have been extensively investigated (Barnova et al, 2025). Recent advances include multivariate empirical mode decomposition (MEMD), which adaptively decomposes multichannel EHG signals into intrinsic mode functions (IMFs), maintaining spectral consistency across channels and avoiding mode-mixing problems (Cui et al, 2025). From MEMD-derived IMFs, Cui et al (2025) extracted 180 features, ultimately selecting eight optimal features using a two-step feature selection algorithm. Entropy-based analysis has emerged as particularly promising. Envelope entropy analysis—calculating Shannon entropy, log-energy entropy, and spectral entropy from EHG signal envelopes—has demonstrated strong discriminative capacity between term and preterm cases (IEEE, 2025). Phase synchronization analysis across multiple electrodes has further revealed that term labor exhibits synchronized, coordinated uterine activity, whereas preterm labor displays weak and uncoordinated patterns (Chowdhury et al, 2026; IEEE, 2025).



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3.2 Machine Learning Approaches

A range of machine learning classifiers have been applied to EHG-based PTB prediction. Chowdhury et al (2026), in a comprehensive scoping review, identified that support vector machines (SVM), decision trees, k-nearest neighbors (K-NN), random forest, and gradient boosting have all been evaluated, with AUC values ranging from 0.93 to 0.99. A particularly innovative approach involves the incorporation of "model error" features, calculated as departures from autoregressive predictions of uterine electrical activity, which serve as a measure of contraction unpredictability (Springer, 2026). This physiologically-informed feature engineering achieved 92.50% accuracy with gradient boosting and 95.85% AUC-ROC with SVM, establishing model error as the strongest predictor (Springer, 2026). Cui et al (2025) employed a cost-sensitive SVM classifier following MEMD-based feature extraction, achieving 94.36% accuracy, 85.16% sensitivity, 96.54% specificity, and 97.31% AUC using the publicly available TPEHG database (300 recordings, 38 preterm). Decision tree classifiers have also shown promise, achieving 85.56% accuracy on imbalanced datasets, though performance on synthetically balanced data was lower, highlighting challenges in minority class classification (European PMC, 2025).

3.3 Deep Learning Architectures

Deep learning has substantially advanced EHG-based PTB prediction. Cholke et al (2025) proposed a multi-head attention-enabled distributed neural network with bidirectional long short-term memory (multi-DNBtM), employing root mean energy-entropy deep features (RMEn2D) to analyze variations across frequency subbands. This framework achieved 96.93% accuracy, 98.45% sensitivity, and 98.19% specificity, demonstrating the power of attention mechanisms in capturing intrinsic patterns in uterine electrical activity. A hybrid multimodal attention network with gated fusion, analyzing 452 recordings from 21–36 weeks gestation across spontaneous, induced, and cesarean births, achieved 98% accuracy, 93% sensitivity, and 99% AUC (Elsevier, 2026). This model incorporated synchronization-aware analysis, revealing that term labor shows increased spatial coordination with stronger activity in the upper right uterine region, whereas preterm activity appears weaker and less organized (Elsevier, 2026). The non-linear synchronization measures, including non-linear interdependence directionality index and normalized permutation cross-mutual information, were statistically significant discriminators ($p < 0.05$) (Elsevier, 2026). Generative adversarial networks have been employed for EHG data augmentation, producing high-quality synthetic signals that maintain statistical properties of actual recordings, addressing the critical challenge of limited labeled data (IEEE, 2025). Deep learning-based automatic semantic segmentation of EHG recordings using UNET 3+ architecture has achieved 91.4% AUC for detecting physiological epochs, enabling robust characterization of uterine myoelectric activity in clinical practice (NIH, 2025).



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4. Personalized Tocolysis Management via EHG Monitoring

4.1 Current Challenges in Tocolysis

Tocolysis, the administration of medications to suppress uterine contractions, represents the primary intervention for threatened preterm labor. However, current tocolytic management follows a generalized approach, with limited ability to predict individual patient response or to determine optimal treatment duration and cessation timing (Mas-Cabo et al, 2020; García-Casado et al, 2025). Tocolytics, including atosiban and nifedipine, are typically administered empirically upon presentation of threatened preterm labor, yet up to 50% of treated patients ultimately deliver at term, suggesting unnecessary exposure and healthcare resource utilization (Mas-Cabo et al, 2020).

4.2 EHG-Based Monitoring of Tocolytic Response

EHG provides a unique opportunity for real-time, objective assessment of uterine response to tocolytic therapy. García-Casado et al (2025) demonstrated that spectral and complexity parameters derived from EHG signals can significantly separate ($p < 0.05$) women who will deliver preterm from those who will deliver at term, both prior to and during tocolytic treatment. Notably, EHG high-frequency content reduces faster in women who ultimately deliver at term compared to those with true preterm delivery during therapy, suggesting differential uterine responsiveness that may guide treatment individualization (García-Casado et al, 2025). Mas-Cabo et al (2020) assessed the feasibility of predicting labor within 7- and 14-day time horizons in women with threatened preterm labor undergoing tocolytic therapy. Using artificial neural networks applied to 140 EHG recordings, they demonstrated that EHG can reliably predict imminent labor regardless of tocolytic therapy stage (Mas-Cabo et al, 2020). The whole EHG window analysis outperformed EHG-burst analysis, representing a significant step toward real-time clinical decision support systems (Mas-Cabo et al, 2020).

4.3 Toward Personalized Tocolysis

The integration of AI-driven EHG analysis enables a paradigm shift from reactive, generalized tocolysis to proactive, personalized management. Personalized baselines, in which a woman's own early-pregnancy EHG calibrates later thresholds, may help manage interpatient variability and improve prediction accuracy (MDPI, 2026). AI models that continuously analyze EHG signals can provide dynamic risk assessments, alerting clinicians to impending delivery and informing tocolytic initiation, dose adjustment, and discontinuation decisions (Chopra et al, 2026). Furthermore, computational models of myometrial cells incorporating EHG data and tocolytic pharmacokinetics are under development to simulate drug effects and support the design of novel therapeutic strategies (Elsevier, 2026). This approach promises to optimize the



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risk-benefit ratio of tocolysis, minimizing unnecessary medication exposure while maximizing efficacy for true preterm labor.

5. Clinical Implementation and Challenges

5.1 Current Evidence and Performance Benchmarks

Table 1 summarizes recent AI-driven EHG-based approaches for preterm birth prediction and their performance metrics.

Table 1. Summary of AI-Driven EHG-Based Preterm Birth Prediction Approaches

Study/Model	Methodology	Dataset	Key Performance Metrics	Clinical Application
Multi-DNBiTm (Cholke et al, 2025)	Multi-head attention + BiLSTM with RMEn2D features	EHG recordings	Accuracy: 96.93%; Sensitivity: 98.45%; Specificity: 98.19%	Preterm labor prediction
MEMD + SVM (Cui et al, 2025)	Multivariate empirical mode decomposition + cost-sensitive SVM	TPEHG (n=300)	Accuracy: 94.36%; Sensitivity: 85.16%; Specificity: 96.54%; AUC: 97.31%	Preterm birth risk diagnosis
Envelope Entropy + AdaBoost (IEEE, 2025)	Entropy analysis of EHG envelopes + SASYN0 oversampling	TPEHG (n=300, 38 preterm)	Accuracy: 96%; Sensitivity: 97%; Specificity: 94%	Preterm labor classification
Hybrid Attention + Gated Fusion (Elsevier, 2026)	Multi-head attention + gated fusion with synchronization features	452 recordings, 21–36 weeks	Accuracy: 98%; Sensitivity: 93%; Specificity: 99%; AUC: 99%	Early preterm detection
Model Error + Gradient Boosting (Springer, 2026)	Autoregressive model error features + ensemble learning	300 pregnancies	Accuracy: 92.50%; AUC-ROC: 94.69%	Term/preterm classification
ANN-based Prediction (Mas-	Artificial neural networks with EHG +	140 EHG recordings,	7- and 14-day labor prediction	Tocolysis management



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Cabo et al, 2020)	obstetric data	TPL women		
UNET 3+ Segmentation (NIH, 2025)	Deep learning semantic segmentation	EHG recordings	AUC: 91.4% (physiological epoch detection)	Clinical screening tool

5.2 Persistent Challenges

Despite remarkable progress, several challenges impede clinical translation. Chowdhury et al (2026) identified that 98.5% of reviewed studies exhibited high risk of bias in the analysis domain, primarily due to limited sample sizes and absence of external validation. Most models have been developed and tested on the same publicly available datasets (primarily TPEHG and PhysioNet databases), raising concerns about generalizability to diverse populations and clinical settings (Chowdhury et al, 2026; Chopra et al, 2026). Standardization remains a critical issue. The lack of unified EHG acquisition protocols, inconsistent electrode configurations, variable preprocessing methods, and non-standardized feature extraction hinder direct comparison of models and impede multicenter validation (Barnova et al, 2025). Class imbalance, with preterm cases constituting a minority in most datasets, poses additional challenges, as models may achieve high overall accuracy while failing to correctly identify at-risk pregnancies (European PMC, 2025; Cui et al, 2025). Furthermore, the integration of EHG-based AI systems into clinical workflows requires addressing computational efficiency, real-time processing capabilities, and user-friendly interface design (Springer, 2026). Model interpretability remains essential for clinician trust and adoption; while deep learning models offer superior performance, their "black box" nature may limit acceptance without explainable AI approaches such as SHAP analysis (Elsevier, 2025).

6. Conclusion and Future Directions

This review establishes that AI-driven EHG signal analysis represents a transformative approach to preterm birth prediction and personalized tocolysis management. Current evidence demonstrates that machine learning and deep learning architectures achieve classification accuracies exceeding 96%, with sensitivities up to 98.5%, substantially outperforming conventional clinical methods. Beyond binary term/preterm classification, EHG-based AI enables dynamic monitoring of uterine contractility patterns, facilitating real-time assessment of tocolytic response and supporting individualized treatment decisions. However, the translation of these promising research findings into routine clinical practice requires addressing several critical gaps. First, large-scale, multicenter prospective cohorts with standardized EHG acquisition protocols are urgently needed to validate existing models and establish robust performance benchmarks across diverse populations. Second, the development of explainable AI frameworks that provide clinicians with interpretable predictions and actionable insights is essential for clinical adoption. Third, integration of EHG with complementary data modalities,



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including maternal clinical characteristics, multi-omics profiling, and fetal monitoring, holds potential for further enhancing predictive accuracy through multimodal approaches. From a clinical perspective, prospective trials evaluating EHG-guided tocolysis management compared to standard care are necessary to demonstrate improved maternal and neonatal outcomes. The development of wearable EHG devices for continuous ambulatory monitoring could enable early detection of preterm labor risk in outpatient settings, facilitating timely intervention and potentially reducing hospitalization rates. On a broader scale, these advances contribute to the emerging paradigm of precision obstetrics, where individualized risk assessment and targeted interventions replace one-size-fits-all approaches to preterm birth prevention and management.

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