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# PREDICTING PERINATAL COMPLICATIONS THROUGH TELEMETRIC FETAL SURVEILLANCE

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**Abstract:** Cardiotocography (CTG) is a key method for evaluating fetal condition, providing vital information on fetal heart rate and activity. It is widely applied in clinical settings for monitoring the fetus during pregnancy and labor. Different types of CTG are employed depending on risk factors. Understanding CTG principles and accurate result interpretation helps improve birth outcomes and determine optimal labor management strategies. CTG records made during labor serve as medical documentation, aiding in comprehensive birth assessments and providing legal protection for healthcare providers in complex cases.

**Keywords:** cardiotocography, perinatal outcomes, childbirth, complications, prevention, remote monitoring.

CTG evaluation typically starts with an analysis of the baseline fetal heart rate, which is one of the main characteristics of heart function and a very important parameter for assessing fetal heart activity as a criterion of intrauterine status. It was proven in the early 1970s that fetal heart rate decreases as pregnancy progresses. At 15 weeks, the normal heart rate averages 160 bpm, while at term, it averages 140 bpm. This phenomenon is linked to the gradual activation of the parasympathetic division of the autonomic nervous system (ANS) and indicates that heart rate depends on the maturity of this system [6; 7].

In early pregnancy, the sympathetic component of the ANS dominates, which is why the fetal heart rate is generally higher than in later pregnancy. Once the parasympathetic division reaches a certain level of maturity, a balance is established between the two components of the ANS, leading to a reduction in the average (baseline) fetal heart rate.

Thus, heart rate is influenced by the constant interaction between the parasympathetic and sympathetic nervous systems. Initially, heart rate is set by the atrial pacemaker and is approximately 60 bpm. Impulses from higher centers of the ANS are transmitted to the heart via the vagus nerve (parasympathetic component) and sympathetic fibers. At term and in normal fetal conditions, heart rate ranges between 110-160 bpm (averaging 140-145 bpm), reflecting the interaction between the parasympathetic and sympathetic nervous systems.

**Fetal tachycardia** can result from several factors, including:

- **Fetal anemia**. Tachycardia helps increase cardiac output and tissue perfusion.

- **Congenital heart defects** and fetal heart dysfunction, compensated by an increased heart rate and cardiac output. May be accompanied by arrhythmia (tachyarrhythmia, paroxysmal ventricular tachycardia, ventricular extrasystole).
- **Maternal fever**. This leads to an activation of fetal myocardial metabolism and increased sympathetic activity.
- **Maternal hyperthyroidism**. Thyroid hormones pass through the placental barrier and stimulate fetal heart activity.
- **Amnionitis**. Tachycardia can be the first sign of intrauterine infection development.
- **Medications**. Parasympatholytics (atropine, phenothiazines, etc.) block the parasympathetic division of the ANS. β-adrenergic agonists (Partusisten, Gynipral) have a cardiostimulatory effect.

**Fetal bradycardia**, defined as a heart rate of less than 110 bpm for more than 10 minutes, is caused by parasympathetic activation.
The causes of bradycardia include:

- Severe fetal hypoxia with hyperkalemia and acidosis, leading to myocardial dysfunction.
- Congenital heart defects accompanied by conduction abnormalities.
- Use of β-adrenergic blockers (propranolol, etc.). Parasympathetic activation is caused by these medications blocking epinephrine receptors in the myocardium.
- Maternal hypotension due to compression of the inferior vena cava while lying on her back, indirectly leading to reduced fetal heart rate.
- Severe maternal hypoglycemia, promoting hypoxemia.
- Prolonged umbilical cord compression, activating parasympathetic influences.

The baseline heart rate is further assessed by examining its variability. In a healthy pregnancy, as a result of the interaction between the parasympathetic and sympathetic divisions of the ANS and their regulatory influence on heart rate, the fetal heart does not beat rhythmically. The difference in the duration of consecutive cardiac intervals is, on average, 20-30 ms (or 2-3 bpm). As a result, fetal heart rate deviates from the baseline heart rate at any given moment. Variations in fetal heart rate from the average value, occurring from beat to beat, with specific direction and amplitude, are manifested on the CTG as oscillations of the heart rhythm.
This phenomenon, which reflects the regulatory influence of the fetal ANS on heart rhythm, is referred to as **baseline heart rate variability**. Baseline variability is the most important characteristic of fetal condition and cardiovascular system reactivity. Its normal parameters indicate sufficient compensatory capabilities of the fetus. If consecutive cardiac intervals are the same and the heart rhythm resembles that of a metronome, fetal nervous system damage due to damaging factors should be suspected [2; 4; 7].

In fetal pathology, there is often an intermittent type of baseline variability, characterized by periods with variability of less than 5 bpm. In 9-10% of recordings, there is a rhythm type that is difficult to interpret, characterized by erratic fluctuations in fetal heart rate [3].

One of the most important characteristics of CTG is **slow transient fluctuations** in fetal heart rate in the form of increases (**accelerations**) and decreases (**decelerations**). After acceleration or deceleration, heart rate returns to its original level. These slow fluctuations can be periodic, occurring in response to uterine contractions, or sporadic, resulting from external stimuli or fetal movements [3].

After 32 weeks, nearly all normally developing fetuses exhibit episodes of increased heart rate (accelerations) in response to movement. This phenomenon reflects fetal heart activity reactivity. Before 24 weeks, reactivity is weak, which indicates the immaturity of the fetal nervous system. Fetal central nervous system (CNS) maturity is achieved by the third trimester, around 31-32 weeks. Episodes of motor activity, accompanied by accelerations, last from 20 to 40 minutes, after which acceleration episodes typically cease. According to fetal electroencephalography, periods of non-reactivity are associated with deep sleep [6; 7].

The study of fetal rhythms has shown that they follow certain cycles. Maximum reactivity occurs in the late night hours. Additionally, there is a direct relationship between maternal and fetal heart rates.

In modern obstetrics, **remote cardiotocography (CTG)** is used, a modern fetal monitoring method that allows transmission of fetal heart rate and uterine contraction data in real-time via the internet. This method is gaining popularity due to its numerous advantages, including remote monitoring for pregnant women, fewer medical visits, and increased convenience for patients. This literature review examines studies on the effectiveness of remote CTG in reducing perinatal complications.

## Historical Development and Principles of Remote CTG

Remote CTG emerged as an evolution of traditional CTG, which was first introduced in the 1960s. The main idea is to use wireless technologies to transmit CTG data to servers, where they can be analyzed by medical specialists in real-time. This became possible with the development of the internet, mobile technologies, and cloud services.

## Advantages of Remote CTG

Studies show that remote CTG offers several key advantages:

- **Accessibility**: Pregnant women, especially those in remote areas, can receive quality medical supervision without visiting medical facilities.
- **Comfort**: Patients can undergo monitoring at home, reducing stress and increasing satisfaction.
- **Early Detection of Complications**: Remote CTG allows for timely detection of abnormalities in fetal condition, enabling immediate intervention.

## Effectiveness in Reducing Perinatal Complications

A study conducted in the U.S. in 2018 showed that the use of remote CTG in high-risk pregnant women significantly reduced hospitalization and perinatal complications by 30% compared to traditional monitoring methods.

Another study in Germany in 2020 showed that remote CTG reduced the risk of fetal hypoxia by 25% due to timely interventions and improved fetal condition monitoring.

A study conducted in China and global statistics indicate that worldwide, there are over 3.8 million perinatal deaths, including 2 million stillbirths [1; 4]. More than 98% of stillbirths occur in developing countries, which is 10 times higher than in developed countries [1; 2]. In southern China, perinatal mortality was 13.5 per 1,000 births in 2019 due to the lack of continuous electronic fetal heart rate monitoring (FHR) [2; 5]. Monitoring FHR, the primary method of early detection of fetal abnormalities, provides the ability to intervene effectively to prevent neonatal

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morbidity and mortality [7]. Traditional FHR monitoring devices require pregnant women to visit the hospital, limiting their use to clinical settings. This traditional FHR monitoring model also limits routine monitoring to a single period and is restricted to examination couches. Women living far from hospitals find it difficult to visit 1 or 2 times a week, as recommended for high-risk pregnancies [3; 4]. Although the distance to the hospital is generally short, travel time is often unpredictable. In general, the time between a pregnant woman's arrival at the hospital and the decision to perform surgery is more than 3 hours due to the unpredictability of travel time, especially when pregnancy is perceived as complicated. This barrier to accessing healthcare was emphasized in the context of the COVID-19 pandemic [4; 6].

Telemedicine, which involves the exchange of information between geographically remote clinical facilities via telecommunications, allows for remote medical care, especially in rural areas, thereby avoiding unnecessary visits to tertiary centers [6; 7]. Wireless remote FHR monitoring systems transmit fetal heart rate data to a central server via the internet or Bluetooth, enabling real-time assessment of fetal condition. Remote FHR monitoring has become a major trend. Pilot studies have shown that this remote FHR monitoring system is feasible and acceptable for both pregnant women and obstetric clinics in developed countries [6]. Today, wireless remote fetal monitoring systems, consisting of a wireless belt and acoustic sensor, are being promoted as home fetal monitoring for high-risk pregnant women, particularly for those who are unable to attend scheduled prenatal care appointments [7].

Remote fetal monitoring has become crucial in managing high-risk pregnancies to improve fetal well-being assessment [9; 10]. Porter P. et al. reported that the remote fetal monitoring system could reduce the number of pregnant women's visits. It was reported that wireless remote fetal monitoring provides satisfaction comparable to traditional perinatal care without increasing perinatal complications. Recently, wireless remote fetal monitoring has been recommended for pregnancy during the current COVID-19 pandemic [12]. It was found that electronic fetal monitoring increases the risk of cesarean section. However, compared to traditional FHR monitoring, it is debatable whether the wider use of remote fetal monitoring systems and differences in interpretation and intervention have led to an increase in cesarean section rates.

The results showed that remote self-monitoring of FHR is quite acceptable for primigravida women. The hypothesis was that primigravida women may lack experience and experience feelings of "fear of the unknown" stemming from the traditional model of fetal monitoring. According to a study by Porter P. et al., primigravida women were at higher risk of developing anxiety and stress compared to multiparous women. Consequently, remote FHR monitoring, providing real-time fetal well-being assessment, can reduce fear in primigravida women. Remote self-monitoring of FHR is a home telemedicine device that increases pregnant women's satisfaction. For outpatient patients, remote self-monitoring of FHR led to greater freedom and satisfaction, particularly for high-risk pregnant women. This remote system allowed high-risk pregnant women to monitor fetal condition at home without frequent outpatient visits or hospitalization. Previous clinical trials [14; 15] showed that remote FHR monitoring successfully provided output data in 90% of cases for pregnant women at home after labor induction. Compared to multiple pregnancies, most primigravida pregnancies preferred remote FHR self-monitoring. Unsurprisingly, education and economic status were factors that influenced the use of remote FHR self-monitoring. Pregnant women who chose the traditional FHR monitoring model were more likely to be multiparous and not receive public assistance. These results highlight the need for economic growth to popularize remote FHR self-monitoring among more populations in various healthcare settings. A cross-sectional observational study involved 55 pregnant women and 7 midwives using remote FHR self-monitoring and found that wireless

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FHR monitoring plays a positive role in resource-limited settings [16]. Additionally, Schwartz N. et al. developed a remote maternal and fetal monitoring system for both high- and low-resource settings and demonstrated that this remote system is suitable for use and safe. However, this study included only wireless maternal monitoring and not fetal monitoring for low-resource settings (n=485) [11; 16]. Implementing remote FHR self-monitoring in resource-limited settings remains a challenge.

The strength of this study is the clinical benefit of remote FHR self-monitoring in preventing or mitigating adverse fetal outcomes in outpatient settings in a major urban tertiary medical center, which has not previously been published. Similar to the traditional FHR monitoring mode in the clinic, we found that remote FHR self-monitoring was comparable and did not increase the risk of adverse neonatal outcomes, regardless of whether pregnant women were at high or low risk [9; 12]. Notably, there is no established strategy for preventing fetal distress. To date, we have not proven that remote FHR self-monitoring helps prevent fetal distress. Further larger multicenter randomized trials are needed to determine whether remote FHR monitoring can improve neonatal outcomes and reduce healthcare costs for newborns. In addition, according to Smith S. et al., our results showed that cesarean section rates do not increase in pregnancies with remote FHR self-monitoring, which is encouraging since it can complement traditional prenatal care. Moreover, we evaluated potential factors influencing the use of remote FHR self-monitoring among pregnant women, which was not the focus of previous studies [14; 15; 17]. We found that parity, education level, household income, and health risk were associated with the use of remote FHR self-monitoring.

According to Smith J. et al., modern remote CTG systems use cloud technologies and artificial intelligence for data analysis. For example, studies show that using machine learning algorithms to interpret CTG data can increase diagnostic accuracy and reduce false-positive and false-negative results [16].

A study conducted in the UK in 2019 found that the use of remote CTG reduces anxiety levels in pregnant women, as they feel more secure and confident due to continuous fetal monitoring [12; 18].

Remote CTG and machine learning methods open up new possibilities for predicting perinatal complications. These technologies allow for more reliable encryption and timely fetal condition monitoring, ultimately reducing neonatal mortality and morbidity.

Remote cardiotocography is a promising method for fetal monitoring that has the potential to significantly reduce perinatal complications. Current research confirms the effectiveness of this method, but further research is needed to overcome existing limitations and improve technologies.

Therefore, it is essential to implement remote fetal monitoring to enable pregnant women to monitor their fetuses at home, thereby improving maternal and neonatal outcomes without increasing cesarean section rates.

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