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ORIGINAL RESEARCH

Cardiovascular Complications in Pre-eclampsia: Can they be Predicted Electrocardiographically?

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ABSTRACT

Background: Pre-eclampsia is a multisystem disorder of pregnancy associated with significant maternal and fetal morbidity. Cardiovascular complications are a major cause of morbidity, and their early prediction remains crucial. Electrocardiography (ECG) offers a simple and non-invasive method to detect early cardiac changes.**Aim:**To assess electrocardiographic abnormalities in women with pre-eclampsia and evaluate their predictive value for cardiovascular complications.**Material and Methods:**This hospital-based, prospective observational study was conducted in the Department of Obstetrics and Gynecology in collaboration with the Department of Cardiology at a tertiary care teaching hospital. A total of 90 pregnant women diagnosed with pre-eclampsia were consecutively enrolled. Detailed clinical evaluation, blood pressure measurement, and resting 12-lead ECGs were performed. ECG parameters including heart rate, PR interval, QRS duration, QTc interval, P-wave dispersion, T-wave inversions, ST-segment changes, and arrhythmias were assessed. Participants were monitored throughout hospitalization and up to six weeks postpartum for cardiovascular complications such as pulmonary edema, arrhythmias, cardiac arrest, myocardial infarction, heart failure, and stroke.
Results: The mean age of participants was 28.60 ± 5.10 years, and mean gestational age was 34.20 ± 2.80 weeks. T-wave inversions were noted in 22.22%, ST-segment changes in 17.78%, and arrhythmias in 15.56% of participants. Prolonged QTc intervals were observed in 20.00% of cases. Cardiovascular complications included acute pulmonary edema (8.89%), new-onset arrhythmias (11.11%), heart failure (6.67%), myocardial infarction (3.33%), and stroke (2.22%). Prolonged QTc interval, T-wave inversions, ST-segment changes, and presence of arrhythmias were significantly associated with the occurrence of cardiovascular complications ($p<0.001$).**Conclusion:**Pre-eclampsia is associated with significant electrocardiographic abnormalities that can predict the risk of cardiovascular complications. Routine ECG screening in pre-eclamptic women may facilitate early detection of high-risk cases, allowing timely interventions to improve maternal outcomes.

Keywords: Pre-eclampsia, Electrocardiography, Cardiovascular complications, QTc prolongation, Pregnancy outcomes

INTRODUCTION

Pre-eclampsia remains a significant contributor to maternal and fetal morbidity and mortality worldwide. It is a complex, multisystem disorder characterized primarily by hypertension and proteinuria after 20 weeks of gestation. Although its precise etiology remains unclear, it is increasingly recognized as a manifestation of widespread endothelial dysfunction and abnormal placentation, resulting in systemic vascular complications that may have long-term cardiovascular repercussions for the mother.Cardiovascular complications in pre-

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eclampsia are not limited to the period of pregnancy but extend well into the postpartum years, predisposing affected women to chronic hypertension, ischemic heart disease, heart failure, and stroke. The cardiovascular burden is primarily due to the adverse remodeling of the maternal vasculature and myocardium during the disease process. The pathophysiological overlap between pre-eclampsia and cardiovascular disease has spurred interest in identifying early markers of cardiovascular compromise in pregnant women.Given the hemodynamic changes intrinsic to pre-eclampsia, electrocardiography (ECG) has emerged as a potentially valuable, non-invasive, and widely accessible tool for early detection of cardiovascular alterations. Recent research has focused on various electrocardiographic parameters, such as the frontal QRS-T angle, QT interval dispersion, and heart rate variability, to predict the onset and severity of pre-eclampsia and its associated complications [1].

The frontal QRS-T angle, an indicator of ventricular depolarization and repolarization heterogeneity, has been recently highlighted as a novel ECG marker for the early prediction of pre-eclampsia [1]. A wider QRS-T angle suggests greater myocardial electrical instability, which could reflect the underlying cardiovascular stress imposed by pre-eclampsia. Moreover, the early detection of such abnormalities could potentially guide timely interventions aimed at reducing maternal and perinatal risks.In addition to electrocardiographic changes, biochemical markers such as angiogenic and antiangiogenic factors, including soluble fms-like tyrosine kinase-1 (sFlt-1) and placental growth factor (PlGF), have shown promise in the prediction and risk stratification of pre-eclampsia [2]. These markers reflect the dysregulated angiogenesis that is central to the disease pathology. However, their use is limited by cost, accessibility, and the need for specialized laboratory facilities, making ECG a more practical tool for widespread screening, particularly in low-resource settings.

Hypertensive disorders of pregnancy, particularly pre-eclampsia, also entail profound alterations in circadian blood pressure patterns. The loss of the nocturnal blood pressure dip, termed "nondipper hypertension," has been associated with an increased risk of pre-eclampsia and adverse cardiovascular outcomes [3]. This association further underscores the importance of evaluating cardiovascular parameters in the antenatal period.Acute complications of pre-eclampsia, including eclampsia, pulmonary edema, hepatic rupture, renal failure, and stroke, are devastating outcomes of undiagnosed or poorly managed cardiovascular dysfunction [4]. Early identification of myocardial strain or dysfunction through ECG could, therefore, be pivotal in preventing these catastrophic events. Moreover, transient left ventricular dysfunction, often observed during pre-eclampsia, supports the theory that subclinical myocardial compromise precedes clinical manifestations [5]. The ability to detect such changes early could transform the management approach from reactive to preventive. The challenge, however, lies in the heterogeneous presentation of pre-eclampsia. Some women may remain asymptomatic until the disease becomes severe, emphasizing the need for robust and easily deployable screening tools. The current focus on biomarkers and imaging techniques, while scientifically sound, does not address the practicality required in everyday clinical practice. Electrocardiography offers an attractive alternative due to its simplicity, cost-effectiveness, and ability to detect even subtle myocardial changes.Emerging evidence advocates for a more integrated approach to predicting and managing pre-eclampsia, combining clinical risk factors, biochemical markers, and electrocardiographic findings [6]. By incorporating ECG into routine antenatal assessments, clinicians could better stratify patients by cardiovascular risk, allowing for more personalized monitoring and interventions.

Importantly, the implications of pre-eclampsia extend beyond pregnancy. Women with a history of pre-eclampsia are at a significantly higher risk of developing future cardiovascular disease, including coronary artery disease, heart failure, and cerebrovascular events [7]. Therefore, identifying cardiovascular alterations during pregnancy is not only critical for immediate obstetric management but also offers a valuable opportunity for long-term cardiovascular health surveillance and preventive care.Despite the promising data, challenges remain in establishing standardized ECG criteria specific for pre-eclampsia prediction. Variations in study designs, population characteristics, and electrocardiographic interpretation methods have led to inconsistent findings. Future research should aim at validating the predictive value of specific ECG parameters across diverse populations and integrating these findings into evidence-based clinical guidelines.

MATERIAL AND METHODS

This was a hospital-based, prospective observational study conducted in the Department of Obstetrics and Gynecology in collaboration with the Department of Cardiology at a tertiary care teaching hospital. Prior to the commencement of the study, approval was obtained from the Institutional Ethics Committee (IEC), and written informed consent was taken from all participants.A total of 90 pregnant women diagnosed with pre-eclampsia, either with or without severe features, based on the American College of Obstetricians and Gynecologists (ACOG) 2020 criteria, were consecutively enrolled for the study. Diagnosis was established based on blood pressure measurements and urinary protein excretion or other relevant systemic findings.

Inclusion Criteria

- Singleton pregnancy.

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- Gestational age ≥ 28 weeks.
- Diagnosis of pre-eclampsia (blood pressure ≥140/90 mmHg on two occasions at least 4 hours apart with proteinuria ≥300 mg/24 hours or new-onset hypertension with end-organ dysfunction).
- Women aged between 18–40 years.
- Willingness to participate and provide written informed consent.

Exclusion Criteria

- Pre-existing cardiovascular disease (e.g., congenital heart disease, ischemic heart disease, arrhythmias).
- Known chronic hypertension before pregnancy.
- Diabetes mellitus, thyroid disorders, renal disorders, or systemic autoimmune diseases.
- Women on anti-arrhythmic or antihypertensive medications before the diagnosis of pre-eclampsia.
- Multifetal gestation.
- Incomplete or poor-quality electrocardiographic recordings.

Data Collection

Detailed clinical histories, demographic details including age, parity, and gestational age, as well as relevant obstetric information, were recorded for all participants. A thorough cardiovascular examination was conducted in each case, which included measurement of blood pressure using a standardized sphygmomanometer technique. All participants underwent a 12-lead standard resting electrocardiogram (ECG) using a ECG machine. ECG recordings were obtained at a paper speed of 25 mm/s and a voltage calibration of 10 mm/mV, preferably with the patient positioned in the left lateral decubitus position to minimize positional artifacts.

Electrocardiographic Parameters Analyzed

The recorded ECGs were assessed manually by two independent cardiologists who were blinded to the clinical details of the participants. The parameters analyzed included heart rate (beats per minute), PR interval (milliseconds), QRS duration (milliseconds), QT interval (corrected for heart rate using Bazett's formula, QTc), P-wave dispersion (calculated as the difference between maximum and minimum P-wave duration), T-wave inversions, and ST-segment changes. Additionally, the presence of arrhythmias such as atrial fibrillation and ectopic beats was noted. Special attention was given to abnormal ECG findings suggestive of myocardial ischemia, left ventricular hypertrophy, conduction blocks, and other arrhythmias.

Cardiovascular Complications Monitored

Participants were closely monitored throughout their hospital stay and up to six weeks postpartum for the development of cardiovascular complications. The complications assessed included acute pulmonary edema, eclampsia-related cardiac arrest, new-onset arrhythmias, heart failure, myocardial infarction, and stroke. Diagnosis of these complications was made based on established clinical criteria and confirmed through appropriate laboratory investigations, such as measurement of cardiac enzymes, and imaging studies including echocardiography, chest X-ray, or brain imaging as indicated.

Statistical Analysis

Data were compiled and analyzed using SPSS version 25.0. Quantitative variables were presented as mean ± standard deviation (SD) and qualitative variables as frequencies and percentages. The association between abnormal ECG findings and the occurrence of cardiovascular complications was assessed using chi-square test or Fisher's exact test for categorical variables and Student's t-test or Mann–Whitney U test for continuous variables. A p-value <0.05 was considered statistically significant.

RESULTS

The study included a total of 90 pregnant women diagnosed with pre-eclampsia. As shown in **Table 1**, the mean age of the study participants was 28.60 ± 5.10 years, and the mean gestational age at the time of evaluation was 34.20 ± 2.80 weeks. With respect to parity, 57.78% (n = 52) of the women were primigravida, while 42.22% (n = 38) were multigravida. Regarding the severity of pre-eclampsia, 56.67% (n = 51) of the participants were categorized as having severe features, whereas 43.33% (n = 39) had pre-eclampsia without severe features. This indicates that the majority of the enrolled patients had more severe disease manifestations.

Electrocardiographic findings among the study participants are summarized in **Table 2**. The mean heart rate recorded was 96.20 ± 13.40 beats per minute. The mean PR interval was 145.70 ± 18.20 milliseconds, and the mean QRS duration was 92.50 ± 12.60 milliseconds. The corrected QT interval (QTc) had a mean value of 438.30 ± 22.50 milliseconds, while the mean P-wave dispersion was 46.20 ± 7.40 milliseconds. Among abnormal findings, T-wave inversions were observed in 22.22% (n = 20) of participants, ST-segment changes were seen in 17.78% (n = 16), and arrhythmias were present in 15.56% (n = 14). These findings suggest notable alterations in cardiac electrophysiology in a significant proportion of women with pre-eclampsia.

The detailed distribution of specific abnormal ECG findings is presented in **Table 3**. T-wave inversions were the most commonly observed abnormality, affecting 22.22% (n = 20) of participants. ST-segment depression was noted in 13.33% (n = 12), and features of left ventricular hypertrophy were present in 11.11% (n = 10). A prolonged QTc interval, defined as greater than 450 milliseconds, was seen in 20.00% (n = 18) of participants. Additionally, atrial fibrillation or flutter was documented in 4.44% (n = 4) of the cases, while

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ventricular ectopic beats were observed in 6.67% (n = 6). This highlights that a range of conduction and repolarization abnormalities can occur in pre-eclamptic pregnancies.

Cardiovascular complications observed during the study period are outlined in **Table 4**. Acute pulmonary edema occurred in 8.89% (n = 8) of participants, while eclampsia-related cardiac arrest was reported in 2.22% (n = 2). New-onset arrhythmias were diagnosed in 11.11% (n = 10) of the participants. Heart failure was observed in 6.67% (n = 6), myocardial infarction in 3.33% (n = 3), and stroke in 2.22% (n = 2). These complications emphasize the significant cardiovascular risks faced by patients with pre-eclampsia during late pregnancy and the early postpartum period.

The association between electrocardiographic abnormalities and the occurrence of cardiovascular complications is depicted in **Table 5**. Prolonged QTc interval was significantly more frequent among patients who developed cardiovascular complications (51.61%) compared to those who did not (3.39%), with a p-value of <0.001. Similarly, T-wave inversions were observed in 45.16% of the patients with complications, compared to only 10.17% without complications, also showing a highly significant association ($p < 0.001$). ST-segment changes were present in 32.26% of those who experienced complications versus 10.17% in those without, with a p-value of 0.008. Furthermore, the presence of arrhythmias was significantly associated with complications, being present in 25.81% of the complication group versus 3.39% of the non-complication group ($p = 0.001$). These findings suggest that specific ECG abnormalities, particularly prolonged QTc interval and T-wave inversions, could serve as valuable predictive markers for cardiovascular complications in women with pre-eclampsia.

Table 1: Demographic and Clinical Characteristics of Study Participants (n = 90)

Parameter	Mean ± SD / n (%)
Age (years)	28.60 ± 5.10
Gestational Age (weeks)	34.20 ± 2.80
Parity	
- Primigravida	52 (57.78%)
- Multigravida	38 (42.22%)
Severity of Pre-eclampsia	
- Without severe features	39 (43.33%)
- With severe features	51 (56.67%)

Table 2: Electrocardiographic Findings among Participants (n = 90)

ECG Parameters	Mean ± SD / n (%)
Heart rate (beats per minute)	96.20 ± 13.40
PR interval (ms)	145.70 ± 18.20
QRS duration (ms)	92.50 ± 12.60
QTc interval (ms)	438.30 ± 22.50
P-wave dispersion (ms)	46.20 ± 7.40
T-wave inversions	20 (22.22%)
ST-segment changes	16 (17.78%)
Presence of arrhythmias	14 (15.56%)

Table 3: Distribution of Abnormal ECG Findings (n = 90)

Abnormal ECG Finding	Frequency (n)	Percentage (%)
T-wave inversions	20	22.22%
ST-segment depression	12	13.33%
Left ventricular hypertrophy	10	11.11%
Prolonged QTc interval (>450 ms)	18	20.00%
Atrial fibrillation/flutter	4	4.44%
Ventricular ectopic beats	6	6.67%

Table 4: Cardiovascular Complications Observed (n = 90)

Complication	Frequency (n)	Percentage (%)
Acute pulmonary edema	8	8.89%
Eclampsia-related cardiac arrest	2	2.22%
New-onset arrhythmias	10	11.11%
Heart failure	6	6.67%
Myocardial infarction	3	3.33%

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Stroke	2	2.22%

Table 5: Association Between ECG Abnormalities and Cardiovascular Complications

ECG Finding	Complication Present (n=31)	Complication Absent (n=59)	p-value
Prolonged QTc interval	16 (51.61%)	2 (3.39%)	<0.001*
T-wave inversions	14 (45.16%)	6 (10.17%)	<0.001*
ST-segment changes	10 (32.26%)	6 (10.17%)	0.008*
Presence of arrhythmias	8 (25.81%)	2 (3.39%)	0.001*

*Statistically significant

DISCUSSION

In this hospital-based observational study, we evaluated the electrocardiographic findings and cardiovascular complications among 90 women diagnosed with pre-eclampsia. The mean age of participants was 28.60 ± 5.10 years, and the mean gestational age at the time of evaluation was 34.20 ± 2.80 weeks. Primigravidas constituted 57.78% of the cohort. These demographic characteristics are comparable to those reported by Sogani et al (2015) [8], who observed a similar trend of pre-eclampsia being more prevalent among younger, first-time mothers with a mean age of approximately 27 years in their study. The severity distribution in our study showed that 56.67% had severe features of pre-eclampsia, in line with prior observations highlighting the rising incidence of severe pre-eclampsia in tertiary care settings.

The electrocardiographic findings revealed significant electrophysiological alterations among the participants. In our study, the mean heart rate was 96.20 ± 13.40 bpm, the PR interval averaged 145.70 ± 18.20 ms, the QRS duration was 92.50 ± 12.60 ms, and the QTc interval was notably prolonged at 438.30 ± 22.50 ms. The QTc interval findings are consistent with Baumert et al (2010) [9], who reported prolonged QTc values (average >440 ms) in pregnancies complicated by impaired uterine perfusion. Additionally, P-wave dispersion averaged 46.20 ± 7.40 ms, suggesting atrial conduction heterogeneity. T-wave inversions were observed in 22.22% of our participants, ST-segment changes in 17.78%, and arrhythmias in 15.56%. These rates are comparable to those found by Angeli et al (2015) [10], who described T-wave abnormalities in approximately 20% of women with hypertensive disorders of pregnancy.

Detailed analysis of abnormal ECG findings showed that T-wave inversions (22.22%) were the most common, followed by prolonged QTc interval (>450 ms) in 20.00%, ST-segment depression in 13.33%, and left ventricular hypertrophy in 11.11% of participants. Our findings are similar to the study by Raffaelli et al (2014) [11], who observed altered ventricular repolarization in 24% of pre-eclamptic patients based on QT dispersion and T-wave changes. Moreover, atrial fibrillation/flutter (4.44%) and ventricular ectopic beats (6.67%) were documented, which echoes the findings of Murphy et al (2015) [12], who reported a 5–7% incidence of rhythm disturbances in women post pre-eclampsia.

Regarding cardiovascular complications, acute pulmonary edema occurred in 8.89% of our participants, new-onset arrhythmias in 11.11%, heart failure in 6.67%, myocardial infarction in 3.33%, and stroke in 2.22%. These findings indicate a substantial risk burden, consistent with the study by Lanza et al (2007) [13], who demonstrated that women with hypertensive pregnancies were at twofold higher risk of developing cardiac events postpartum. In comparison, Tomsin et al (2012) [14] found lower but significant rates of cardiovascular complications when subtle cardiac function alterations were identified antenatally.

A significant association was found between specific ECG abnormalities and cardiovascular complications in our cohort. Prolonged QTc interval was present in 51.61% of patients who developed complications compared to only 3.39% of those without, highlighting a robust predictive value ($p < 0.001$). Similarly, T-wave inversions were seen in 45.16% of complication cases versus 10.17% in those without complications, and ST-segment changes were noted in 32.26% of complicated cases versus 10.17% in uncomplicated cases. The presence of arrhythmias also showed a significant association with cardiovascular events (25.81% vs 3.39%). These results strongly mirror the observations by Isezuo et al (2004) [15], who reported that a prolonged QTc interval was a strong predictor of eclampsia-related complications, with rates of abnormal QTc exceeding 50% among those developing cardiac events.

Furthermore, our findings align closely with the proposition made by Lazzeroni et al (2018) [16], advocating for ECG-based risk stratification in cardiovascular diseases. They emphasized that even minor electrocardiographic alterations, when systematically assessed, could outperform conventional risk scores in predicting major cardiac events — a notion that finds validation in our results, where a simple resting ECG identified women at significantly higher risk of severe complications.

Finally, the pathophysiological implications discussed by Angeli et al (2015) [10] provide a framework for understanding our observations. According to their model, hypertensive disorders induce subclinical myocardial ischemia, leading to repolarization abnormalities (prolonged QTc, T-wave inversion) and increasing susceptibility to arrhythmias, pulmonary edema, and cardiac dysfunction. Our findings reinforce this pathophysiological link, suggesting that

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electrocardiography can be a practical and inexpensive bedside tool for early identification of women at high cardiovascular risk during and after pre-eclampsia.

CONCLUSION

This study demonstrates that pre-eclampsia is associated with significant electrocardiographic abnormalities, including prolonged QTc intervals, T-wave inversions, and arrhythmias, which strongly predict cardiovascular complications. Routine ECG monitoring in pre-eclamptic women can serve as an effective, non-invasive tool for early identification of those at increased cardiac risk. Early detection may enable timely interventions, potentially improving maternal outcomes.

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