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Original Article *Özgün Araştırma*

EVALUATION OF THE FRONTAL-PLANE QRS-T ANGLE IN PREGNANCY

Gebelikte Frontal QRS-T Açısının Değerlendirilmesi

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ABSTRACT

Objective: Our aim in this study was to evaluate changes in the frontal QRS–T (fQRS-T) angle, which is an important indicator of repolarisation defects and arrhythmogenic predisposition, in pregnant women relative to non-pregnant women and between trimester groups.

Material and Methods: One hundred fty-seven pregnant women with no history of cardiac or chronic disease and 150 healthy non-pregnant women as a control group were included in this study. PR, QRS, QT, corrected QT and fQRS-T angles were calculated manually. Subgroup analysis was performed to investigate the eects of changes in trimester on ECG of 58 pregnant women, whose ECG data of all three trimesters could be accessed.

Result: The mean age of study participants was 31±7 years. The heart rates of pregnant women and the control group were 83±12 bpm and 76±14 bpm respectively (p<0.001), while fQRS–T angles measured 27.6°±17.7° and 20.7°±6.6° respectively (p<0.001). The frontal QRS-T angle was also detected signicantly decrease in the progression from the rst trimester (34.4±15.4) to the second (26.5±14.8) and third (23.3±20.3) trimesters (p=0.003). Gestational week had a statistically signicant negative correlation with fQRS-T angle (r = −0.233; p=0.003).

Conclusion: The fQRS-T angle, even if remained with-in the normal range was larger in pregnant women than in non-pregnant women and also larger in rst trimester pregnant women relative to those in the second or third trimester.

Keywords: *Arrhythmia, electrocardiogram, frontal QRS-T angle, pregnancy, ventricular repolarisation*

ÖZ

Amaç: Bu çalışmadaki amacımız gebe kadınlarda repo-larizasyon defekti ve aritmojenik yatkınlığın önemli bir göstergesi olan frontal QRS–T (fQRS-T) açısındaki değişik-liklerin gebe olmayan kadınlara ve trimester gruplarına göre değerlendirmektir.

Gereç ve Yöntemler: Çalışmaya kardiyak veya kronik hastalık öyküsü olmayan 157 gebe ve kontrol grubu olar-ak 150 sağlıklı gebe olmayan kadın dahil edildi. PR, QRS, QT, düzeltilmiş QT ve fQRS-T açıları manuel olarak hes-aplandı. Her üç trimesterin EKG verilerine erişilebilen 58 gebe kadının EKG'sinde trimester değişikliklerinin etkiler-ini araştırmak için alt grup analizi yapıldı.

Bulgular: Çalışmaya katılanların yaş ortalaması 31±7 yıl idi. Gebelerin ve kontrol grubunun kalp atım hızları sırasıy-la 83±12 bpm ve 76±14 bpm (p<0.001) iken, fQRS–T açıları sırasıyla 27.6°±17.7° ve 20.7°±6.6° olarak ölçüldü (p<0.001). Frontal QRS-T açısında da birinci trimesterden (34.4±15.4) ikinci (26.5±14.8) ve üçüncü (23.3±20.3) trimesterlere (p = 0.003) ilerlemede anlamlı azalma saptandı. Gebelik haftası fQRS-T açısı ile istatistiksel olar-ak anlamlı negatif korelasyon gösterdi (r = -0.233; p = 0.003).

Sonuç: fQRS-T açısı, normal aralıkta kalsa bile, gebe kadınlarda gebe olmayanlara göre ve aynı zamanda birin-ci trimester gebe kadınlarda ikinci veya üçüncü trimestere göre daha büyüktü.

Anahtar Kelimeler*: Aritmi, elektrokardiyogram, frontal QRS-T açısı, gebelik, ventriküler repolarizasyon.*

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INTRODUCTION

Pregnancy is a dynamic process in which maternal physiological compensatory mechanisms function to meet both increased maternal and fetal metabolic needs and to support uteroplacental circulation so as to ensure an adequate level of fetal development. These compensatory physiological changes, which begin in the first trimester of pregnancy, have significant e-ects on the maternal cardiovascular system, reducing peripheral vascular resistance and increasing the plasma volume, heart rate (HR) and cardiac output (1). In particular, hemodynamic and hormonal changes associat-ed with pregnancy a-ect the maternal heart: eccentric hypertrophy may arise during pregnancy, marked by enlargements of the heart cavities and increases in left ventricular wall thickness and mass (2). Cardiac remodelling increased sympathetic tone and pregnancy-related hormonal changes can have proarrhythmic e-ects (3). It was found that 22.2% of maternal mortality during and after pregnancy was due to cardiovascular causes, with arrhythmic events being the third most common etiology among cardiovascular causes (4).

The frontal QRS–T-wave (fQRS-T) angle, which can also be dened as the angle between ventricular depolarisation and repolarisation, has emerged as a new marker of ventricular repolarisation heterogeneity. The QRS-T angle is an indicator of repolarisation abnormalities of the heart, which may vary depending on age, sex and measurement technique. Although the upper limit for arrhythmic predisposition varies between di-erent cohorts and study endpoints, the upper limit defined for the group of patients we evaluated in our study was >43°. Frontal QRS-T angle is an easily computable parameter in clinical practice that has been shown to be associated with sudden cardiac death, ventricular arrhythmias, cardiovascular mortality, and all-causes death (5). But information about the changes in fQRS-T angle in pregnant wom-en relative to healthy non-pregnant women and its progression during the course of pregnancy is limited. In our study, we sought to evaluate the relationship between fQRS-T angle in pregnant women without a history of cardiovascular or chronic disease and healthy women in a non-pregnant control group. In addition, we aimed to evaluate the e-ect of trimester changes on ECG parameters and fQRS-T angle with the subgroup analysis we conducted in our study.

MATERIAL AND METHODS

From August 2019 to March 2021, 157 consecutive pregnant women admitted to the cardiology outpatient clinic with atypical chest pain, palpitations, or dyspnea and 150 healthy women of a similar age range were included in our study. Our study exclusion criteria were (i) multiple pregnancies; (ii) diabetes mellitus or hypertension; (iii) coronary heart disease or congenital heart disease; (iv) advanced heart valve disease or congestive heart failure; (v) gestational hypertension, eclampsia or preeclampsia; (vi) inammatory, immu-nological or rheumatic disease; (vii) antiarrhythmic drugs or other drugs use which may a-ect the duration of QT interval, (viii) additionally, those with electrocardiograms (ECGs) showing atrial fibrillation; complete or incomplete bundle branch block; ST changes; U-wave presence or T-wave negativity; (ix) electrolyte imbalance; (x) renal, hepatic or thyroid dysfunction; or (xi) presence of permanent pacemaker.

In our study, demographics, ECG findings and laboratory tests of the pregnant and control groups were compared. An attempt was made to create the most appropriate cohort possible in terms of age and body mass index (BMI) characteristics in the control group. Ejection fraction, haemoglobin, creatinine, sodium, potassium, calcium, iron, ferritin and thyroid hormone results were then evaluated.

In ECG analyses, first-admission ECGs of pregnant women and healthy non-pregnant women were evaluated. For subgroup analysis, 58 pregnant women whose ECG records of all three trimesters could be accessed were evaluated. Thus, the changes in ECG findings and fQRS-T angle with the tri-mester change of the same pregnant woman were evaluated. ECG records were obtained with a speed of 25 mm/s and a width of 10 mm/mV by placing electrodes in standard ana-tomical localities after patients had rested for 10 minutes in the supine position (Cardiofax GEM, model 9022 K, Nihon Kohden, Tokyo, Japan). To improve the accuracy and reliability of our measurements, ECGs were recorded in our local online imaging program. In our study, manual ECG meas-urements were evaluated by two cardiologists using callipers and magnifying lenses. One of the ECG evaluators was from the authors and the other was a cardiologist with no con-ict of interest, who was blinded to the demographic data of the patients. Interobserver coecients of variation was 2.1%. Baseline ECG measurements of HR, PR interval, QRS interval, QT interval and QTc interval calculated using Bazett Formula [cQT=QT√(R–R interval)] were obtained manually. Measurements were calculated by averaging the values obtained separately from each derivation of the 12-lead ECG. One measurement was taken from each derivation, but at least two consecutive measurements were averaged so as to improve accuracy in derivations where the image quality was not good. ECGs were included in the study data if at least eight of the 12 leads could be measured.

The frontal QRS-T angle was calculated as the absolute value of the difference between the frontal-plane QRS and T-wave axes. If such a difference was greater than 180°, then the QRS-T angle was adjusted to the minimal angle as 360° minus the absolute value of the difference between the fron-tal-plane QRS and T-wave axes (5) (Figure 1).

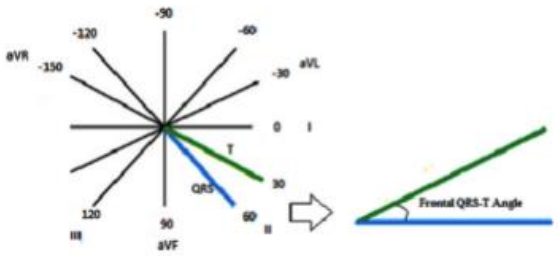

Figure 1: An illustration of the measurement of frontal QRS-T angle. Frontal QRS-T angle= Difference of QRS axis - T axis.

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The study was approved by Trabzon Kanuni Training and Research Hospital Clinical Research Ethics Committee (date: 10.06.2021, issue number: 2021/96). All procedures were made in compliance with the principles of the Helsinki Declaration.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences version 26 (IBM Corporation, Armonk, NY, USA). Categorical and continuous variables were expressed as numbers or percentages. The Kol-mogorov–Smirnov test was used to determine the normal distribution of parameters, and the chi-squared test was used to compare categorical variables.

Age, ejection fraction and laboratory results demonstrat-ed no signi-cant dierences between the groups. BMI was found to be statistically signi-cant in pregnant women [30.4±3.27 vs 28.6±2.04 kg/m2; p=0.017]. It was observed that PR, QRS and QT intervals were lower in pregnant women than in the control group (p<0.001). In contrast, in pregnant women compared to the control group, HR [83±12 bpm and 76±14 bpm (p<0.001), respective-ly] and frontal QRS-T angle [27.6°±17.7° and 20.7°±6.6° (p<0.001), respectively] were found to be signi-cantly higher.

Continuous data consisting of independent measurements and normal distribution were analysed using independ-ent-samples t-tests and one-way analysis of variance. Pearson test was used for analysis of correlations between ECG -ndings and clinical features. A two-tailed p-value of 0.05 or less was considered to be statistically signi-cant.

RESULTS

Demographic, laboratory, and ECG data of 157 pregnant women and 150 healthy women included in our study are presented in (Table 1).

Table 1: The characteristics, laboratory tests results, and electrocardiographic findings of the study population.

Variables	All (n=307)	Pregnancies (n=157)	Healthy women (n=150)	P value
Age **(years)**	31.11±7.45	29.86±5.41	32.09±7.38	0,089
BMI (kg/m^2)	29.2±1.21	30.4±3.27	28.6±2.04	**0.017**
Heart rate **(bpm)**	80.48±13.73	83.99±12.46	76.80±14.06	**<0.001**
PR interval **(ms)**	147.62±19.83	143.56±19.09	151.87±19.76	**<0.001**
QRS interval **(ms)**	84.90±8.02	83.18±7.34	86.70±8.32	**<0.001**
QT interval **(ms)**	364.95±27.15	356.30±24.64	374±26.78	**<0.001**
QTc interval **(ms)**	400.44±17.81	398.80±18.06	402.16±17.43	0.098
Frontal QRS-T angle	24.24±13.93	27.61±17.73	20.72±6.69	**<0.001**
Ejection fraction **(%)**	60.1±3.16	59.7±4.21	60.4±5.12	0.843
Hemoglobin **(g/dl)**	12.05±1.07	12.01±1.57	12.76±2.82	0.722
Creatine **(mg/dl)**	0.67±0,12	0.58±0.22	0.78±0.43	0.646
Sodium **(mEq/L)**	137.80±1.33	138.50±1.67	137.21±2.44	0.943
Potassium**(mEq/L)**	4.15±0.26	4.11±0.66	4.15±0.29	0.430
Calcium**(mEq/L)**	9.51±0.44	9.89±0.64	9.37±0.52	0.577
Iron **(µg/dL)**	69.7±25.16	64.3±15.12	69,9±21.6	0.854
Ferritin **(nl/mg)**	27.85±12.99	27.80±8.93	29.1±12.04	0.143
TSH **(µlu/mL)**	1.57±0.97	1.56±0.26	1.58±0.77	0.121

A total of 423 ECGs were evaluated within the scope of our study. 157 of the evaluated ECGs belonged to the -rst admission examinations of pregnant women, and 150 ECGs belonged to healthy non-pregnant women. 58 pregnant women had ECG data of all three trimesters. During tri-mester subgroup analysis, ECG measurement parameters between groups were compared, and their results are presented in (Table 2).

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Table 2: Electrocardiographic Measurements in Pregnant Women in First, Second, and Third Trimesters of Pregnancy

Variables	First Trimester (n=45)	Second Trimester (n=54)	Third Trimester (n= 58)	P value
Heart rate **(bpm)**	82.49±10.95	83.28±12.63	86.00±13.40	**0.012**†
PR interval **(ms)**	146.54±17.77	141.65±18.17	143.02±20.87	0.181
QRS interval **(ms)**	85.37±7.15	82.70±6.96	81.93±7.57	**0.021**†
QT interval **(ms)**	358.93±21.02	351.67±25.05	358.58±26.57	0.126
QTc interval **(ms)**	399.40±14.99	398.86±14.37	398.27±22.95	0.856
P wave angle	51.84±24.73	47.85±21.49	37.50±27.92	**0.008****
QRS wave angle	60.53±20.57	55.24±26.10	50.77±18.56	**0.013**†
T wave angle	33.93±21.37	33.92±14.01	28.86±15.87	0.077
Frontal QRS-T angle	34.46±15.49	26.50±14.88	23.32±20.31	**0.003***

*:Significant di-erence is between both rst trimester–second trimester,first trimester–third trimester.
**:Significant di-erence is between both rst trimester–third trimester, second trimester- third trimester.
†:Significant di-erence is between only rst trimester–third trimester.

HR was observed to increase numerically in the progression from the first trimester to the second and third trimes-ters, respectively. It was found that this numerical di-erence was significant between the first and third trimester groups. It was also observed that PR, QT and QTc intervals did not exhibit a significant di-erence between trimester groups. The QRS interval was found to be significantly lower in the third trimester group than in the first trimes-ter group. It was observed that the P- and QRS-wave axes tended to decrease numerically from the first trimester to the second and third trimesters, respectively, in a statistically significant manner. The fQRS-T angle was also found to demonstrate a statistically significant difference between the trimester subgroups. It tended to decrease significantly from the first trimester to the second and third trimesters, respectively. However, no significant difference between subgroups regarding the T-wave axis was apparent.

Correlation analysis was performed to evaluate the relationship between ECG findings and clinical characteristics (Table 3) and it was found that the gestational week had a statistically significant negative correlation with the QRS interval, P-wave axis and fQRS-T angle.

Table 3: Correlation analysis between electrocardiographic findings and clinical characteristics in pregnants.

	Gestational Week	Maternal Age	BMI	Heart Rate
Heart rate **(bpm)**	r: 0.022 p: 0.783	**r: -0.245** **p: 0.001**	r: 0.114 p:0.061	
PR interval **(ms)**	r: -0.107 p: 0.183	r: 0.059 p: 0.433	r: 0.112 p:0.060	**r: -0.195** **p: 0.001**
QRS interval **(ms)**	**r: -0.214** **p: 0.007**	**r: 0.257** **p: 0.001**	r:0.013 p:0.060	**r: -0.230** **p<0.001**
QT interval **(ms)**	r: -0.015 p: 0.849	**r: 0.369** **p<0.001**	r:0.110 p:0.078	**r: -0.760** **p<0.001**
QTc interval **(ms)**	r: -0.042 p: 0.604	**r: 0.227** **p: 0.002**	r: -0.070 p:0.231	**r: -0.316** **p: 0.003**
P wave angle	**r: -0.210** **p: 0.008**	r: 0.027 p: 0.892	r: -0.108 p:0.077	**r: 0.180** **p: 0.024**
Frontal QRS-T angle	**r: -0.233** **p: 0.003**	r: -0.120 p: 0.112	r:0.107 p:0.079	**r: -0.294** **p: 0.002**

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DISCUSSION

We obtained the following primary results in our study: (i) in pregnant women, significantly greater fQRS-T angle was observed and (ii) fQRS-T angle is greater during the first trimester than the second or third trimester. In other words, the frontal QRS-T angle was significantly reduced as the pregnancy progressed.

Pregnancy is a dynamic process in which compensatory mechanisms work at hemodynamic and hormonal levels to ensure fetal growth and development and meet increased fetal and maternal metabolic needs. These compensatory mechanisms have significant effects on the maternal cardiovascular system (1). During pregnancy, the HR tends to rise with pregnancy progression. Although many hemodynamic changes reach their maximum level in the second trimester, the increase in HR reaches its maximum in the third trimester. According to its basal value, the HR may increase by a total of 20% to 25% (6,7). Hemodynamic and hormonal changes can trigger increases in left ventricular wall thickness by up to 28%, left ventricular mass by 52% and right ventricular mass by up to 40% (8). Studies in pregnant mice have shown that transient cardiac remod-elling associated with volume overload and ventricular hypertrophy occurs. (9). In a normal pregnancy, a slight dilatation is observed in the four heart chambers. This dilatation is higher in the right atrium and ventricle compared to the left atrium and ventricle (10). The fact that all these described hemodynamic and hormonal changes contributed to the development of ECG changes, the repolarisation defects and arrhythmogenic predisposition in pregnant women relative to healthy women was also supported by our study results. In addition, the common point of all these hemodynamic and hormonal changes begins in the early stages of pregnancy, reaches a peak in the second trimester, and then progresses in a plateau course. This course of changes suggests that adaptation and / or protective mechanisms also work in the process. Therefore, we think that the response to these physiological compensatory changes before the adaptation mechanisms of the maternal cardiovascular system in the first trimester may increase the tendency towards repolarization defects and arrhythmogenic tendencies. In our study, we believe that greater detection of the fQRS-T angle in the first trimester subgroup relative to the other trimester subgroups may be associated with this issue.

The fQRS-T angle has been shown to be associated with sudden cardiac death, ventricular arrhythmias, cardiovascular and all-cause mortality (5). Wide fQRS-T angle was associated with decreased left ventricular ejection fraction and increased left ventricular end-diastolic volume in patients with chronic renal failure (11). It is the basis of our hypothesis that fQRS-T angle, which has been proven to be associated with compensatory changes and remodelling in the cardiovascular system, may also be associated with cardiovascular changes occurring during pregnancy. And backed by the results we have achieved.

We found that HR was significantly higher in pregnant women than in the control group and in the third trimester versus the first or second trimesters.

Our conclusion is consistent with the compensatory physiological changes of pregnancy. In addition, in our correlation analysis, our determination that there is a significant negative correlation of HR with the PR, QRS, QT and QTc intervals supports the validity of our findings.

It was found that gestational week had a statistically significant negative correlation with the QRS interval, P-wave axis and fQRS-T angle. This negative correlation relationship between gestational week and fQRS-T angle is a val-uable finding that supports the difference and change in fQRS-T angle across our trimester groups.

Decrease of frontal QRS-T angle from first trimester to third trimester, negative correlation between gestational week and fQRS-T angle; can be explained by the inability of the pregnant woman to adapt to the hemodynamic changes that begin in the first trimester. Although these he-modynamic changes peak in the later stages of pregnancy, the decrease in fQRS-T angle can be interpreted as the beginning or the optimal level of hemodynamic adaptation.

The frontal QRS-T angle was found to be higher in pregnant women than in healthy non-pregnant women and in the first trimester than in the second and third trimester groups, respectively, even if it remained within the normal range. This result may be important for tailoring follow-up plans, especially in terms of cardiovascular complications, in pregnant women in the first trimester.

Statements

Conflicts of interest: There are no conicts of interest for authors in terms that are not clear and may affect their decisions on the content of their work (such as financial or personal interests).

Researchers' Contribution Rate Statement: Concept/Design: EY; Analysis/Interpretation: EA; Data Collection: KİAY; Writer: EY; Critical Review: KİAY; Approver: EA

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