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Relationship between morning blood pressure surge and the frontal plane QRS-T angle in newly diagnosed hypertensive patients

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ABSTRACT

Background: Morning blood pressure surge (MBPS) plays an important role in target organ damage and major adverse cardiac events. The frontal QRS-T [f(QRS-T)] angle is the electrocardiographic marker and index of ventricular arrhythmogenic events. We aimed to investigate the relationship between MBPS and the f(QRS-T) angle, which is an indicator of ventricular repolarization disorder, in patients with newly diagnosed HT.

Methods: Between June 2020 and March 2021, 263 patients with newly diagnosed HT who were admitted to our outpatient clinic were prospectively included in the study. According to ambulatory blood pressure monitoring (ABPM), the patients were categorized into two groups: Group-I: low-value MBPS (<37 mm Hg), and group-II: high-value MBPS (≥37 mm Hg). The f(QRS-T) angle calculated from the 12-lead electrocardiogram and all other data were compared between the groups.

Results: A total of 186 newly diagnosed HT patients who met the inclusion criteria were included in the study. The average f(QRS-T) angle in Groups I and 2 was $21^\circ \pm 16^\circ$ and $51^\circ \pm 30^\circ$, respectively ($P < .001$). According to multivariate regression analysis, T peak-end and MBPS were found to be independent predictors of the f(QRS-T) angle.

Conclusions: As a result of our study, we found that the f(QRS-T) angle was widened in patients with exaggerated MBPS. The cause of increased cardiovascular outcomes in patients with exaggerated MBPS may be explained by widened in the f(QRS-T) angle that is a ventricular repolarization parameter.

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Introduction

Hypertension (HT) is a major cardiovascular disease that affects 30% to 45% of the population and causes serious morbidity by target organ damage (1). Left ventricular hypertrophy, retinopathy, nephropathy, coronary artery disease and cerebrovascular diseases can be listed as some of the target organ damages. The occurrence of target organ damage in a hypertensive patient was shown to be clinically associated with a poor prognosis (2). Besides, clinical studies show that most major cardiovascular events, including myocardial infarction, stroke, and sudden cardiac death, often occur within the first 4–6 hours after awakening due to the rise in blood pressure in the morning (3–6). Therefore, morning blood pressure surge (MBPS) plays an important role in target organ damage (7,8). Additionally, exaggerated MBPS is an independent risk factor for mortality and cardiovascular and cardiac outcomes (9,10).

In hypertensive patients, left ventricular hypertrophy, myocyte hypertrophy and collagen deposition in the interstitium occur. As a result, the homogeneous structure of the left ventricle is disrupted by increasing the amount of fibrotic tissue in

the myocardium (11,12). This leads to a change in myocardial repolarization and triggers ventricular arrhythmia (13). Hypertensive cardiomyopathy, disrupted function of voltage-dependent potassium channels and autonomic irregularity cause the development of pathologically prolonged and heterogeneous repolarization, resulting in the electrical imbalance observed in HT (14). Disturbances in myocardial conduction can be determined with the frontal plane QRS-T [f(QRS-T)] angle, a new repolarization parameter in 12-lead electrocardiography (ECG). The f(QRS-T) angle is described as the angle between the directions of ventricular depolarization (QRS axis) and repolarization (T axis). It was determined as a new marker of heterogeneity in ventricular repolarization and disturbances in myocardial conduction, and is considered as an index of the transmural dispersion of repolarization (15,16). The f(QRS-T) angle is the electrocardiographic marker and index of ventricular arrhythmogenic events (16). Recent studies have indicated that an increase in the f(QRS-T) angle was associated with a poor clinical course (12,15,17); thus, the f(QRS-T) angle can provide a good correlation in risk estimation compared to other repolarization parameters (18,19).

MBPS affects ventricular repolarization parameters by causing ventricular remodeling. This effect was associated with fatal cardiac arrhythmias and adverse cardiac outcomes (8,9,20). The f(QRS-T) angle is an important indicator of repolarization disturb, which has been especially emphasized recently (15–17). Although several studies have investigated the relationship between HT and parameters of repolarization, the relationship between MBPS and the f(QRS-T) angle has not been investigated to date. In the current study, we aimed to investigate the relationship between MBPS and the f(QRS-T) angle, which is an indicator of ventricular repolarization disorder, in patients with newly diagnosed HT.

Material and methods

Study population

Between June 2020 and March 2021, 263 patients with newly diagnosed HT who were admitted to our outpatient clinic were prospectively included in the study. After a detailed medical history and physical examination, the patient's age, gender, height, weight, smoking history, and family history of coronary artery disease were questioned and recorded. Additionally, data on medications used by the patients were recorded. Electrocardiogram (ECG), routine laboratory analysis, echocardiographic evaluation and ambulatory blood pressure monitoring (ABPM) were performed on all patients. Based on these preliminary analyses, patients meeting the following criteria were excluded: known coronary artery disease ($n = 17$), LVH ($n = 16$), hyperthyroidism ($n = 5$), right and left bundle branch block on ECG ($n = 11$), electrolyte imbalance ($n = 5$), systolic heart failure ($n = 7$), secondary hypertension ($n = 3$), chronic kidney, and liver failure ($n = 8$), valvular heart disease ($n = 5$) and use of any drugs that could affect cardiac repolarization such as antiarrhythmic medications ($n = 0$). Thus, a total of 186 patients were included in the final study group. The diagnosis of diabetes mellitus was determined by a fasting blood glucose of 126 mg/dL or higher, or use of anti-diabetic medication. Hyperlipidemia was determined as total cholesterol level of 200 mg/dL or higher, or a history of statin use. Body mass index (BMI) was calculated with the following formula: $BMI = \text{weight (kg)} / \text{height}^2 (\text{cm}^2)$.

Ambulatory blood pressure measurements

Noninvasive 24-hour ABPM was measured on a normal day of activity using an automatic reading and recording device (PKHEM-7102-E-03, Omron Healthcare Co., Japan). Cuff sizes suitable for the arm circumference of each patient were selected and applied. The device was set to take measurements every 20 minutes and recorded 72 measurements in approximately 24 hours. Patients were told to record sleep duration and morning waking time. Sleep BP was defined as the average of BP measurements during the time the patient was in bed, and awake BP was defined as the average of BP measurements recorded during the rest of the day. We classified subjects nocturnal BP fall as follows: riser if the nocturnal BP fall was <0%, non-dippers if it was between 0% and 10%, dippers if it

was >10% and extreme dippers if it was >20% (21). Height (cm) and weight (kg) measurements of the patients were recorded.

Diagnosis of hypertension and measurement of morning blood pressure surge

The daily average values of the blood pressure (BP) measured by ABPM for 24 hours in each patient was used for diagnosis. Based on the 2018 ESC/ESH Guidelines for the management of arterial hypertension (1), high normal was defined as systolic BP between 130 and 139 mmHg and/or diastolic BP between 85 and 89 mmHg. Stage 1 hypertension was defined as systolic BP between 140 and 159 mmHg and/or diastolic BP between 90 and 99 mmHg. Stage 2 hypertension was defined as systolic BP between 160 and 179 mmHg and/or diastolic BP between 100 and 109 mmHg. Stage 3 hypertensive was defined as systolic BP > 180 mmHg and diastolic BP >110 mmHg. Accordingly, patients with systolic BP >140 mmHg and diastolic BP >90 mmHg were included in the current study.

While calculating MBPS, the sleep and wake hours recorded by the patients were first examined. Then, the difference between the lowest-measured systolic BP at night and the mean systolic BP 2 hours after waking up was recorded as MBPS (22). Due to there is currently no worldwide cutoff value to determine exaggerated MS in the literature, we performed two ways to identify groups according to MBPS. First way, we evaluated according to previous studies, a pressure surge of 37 mmHg and above was considered significant (23,24). Secondly, we used the median value of MBPS for the cutoff value of MBPS in the study population. Similarly, a pressure surge of 37 mmHg was the median value of our study population too. The patients were categorized into 2 groups: Group-I: low-value MBPS (<37 mmHg), and group-II: high-value MBPS (≥ 37 mmHg) according to a meta-analysis including eight different populations by Li et al. (24) and our study population.

Electrocardiography

A 12-lead ECG at a speed of 50 mm/s was carried out on all patients recruited to the current study (Nihon Kohden, Tokyo, Japan). The ECG data from all patients were scanned, saved in a computer and evaluated by two cardiologists at 400% magnification. The QT interval, Tpe interval, corrected QT interval and the f(QRS-T) angle were calculated with the appropriate method (25). The Tpe interval was measured in precordial leads that are considered to reflect the transmural axis of the left ventricle, and therefore to provide an index of transmural dispersion of repolarization (26). The baseline method was used to measure of Tpe interval and the widest interval was recorded. The Tpe dispersion was not calculated since the relationship between the f(QRS-T) angle and MBPS was the main target. ECGs with U waves were excluded from the study. The f(QRS-T) angle was calculated as the difference between the frontal plane QRS axis and the T axis (16); the latter two parameters are automatically calculated by the ECG device (Figure 1). To evaluate the effect of the QRS-T angle on clinical variables, the median value was accepted as 31° . The study population was divided into two groups: group-I: narrow angle (< 31°) and group-II: wide angle ($\geq 31^\circ$).

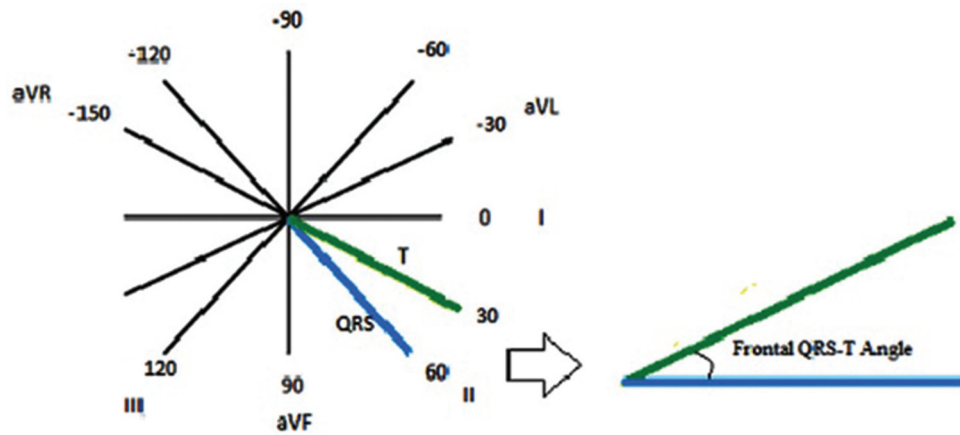


Figure 1. Measurement of a frontal plane QRS-T angle.

Table 1. Demographic and biochemical characteristics according to morning blood pressure surge.

Variables	Group I: MBPS < 37 mmHg (n = 91)	Group II: MBPS ≥ 37 mmHg (n = 95)	P value
Age (years)	47.9 ± 15	54 ± 14	0.011
Female gender, n (%)	45(49)	56(58)	0.145
Diabetes mellitus, n (%)	11(12)	12(12.6)	0.910
Hyperlipidemia, n (%)	35(38.5)	38(40)	0.830
Height (cm)	163 ± 10	163 ± 8	0.578
Weight (kg)	76 ± 13	80 ± 16	0.029
Body mass index	27 ± 4.8	29 ± 4.6	0.036
Heart rate (beats)	80 ± 12	78 ± 9	0.442
Ejection fraction (%)	66 ± 2.3	65 ± 2.6	0.496
Total cholesterol (mg/dl)	191 ± 49	200 ± 38	0.243
HDL cholesterol (mg/dl)	47 ± 12	43 ± 13	0.320
LDL cholesterol (mg/dl)	124 ± 31	128 ± 31	0.528
Triglycerides (mg/dl)	165 ± 109	162 ± 155	0.908
Creatinine (mg/dl)	0.7 ± 0.19	0.81 ± 0.74	0.098
Glucose (mg/dl)	103 ± 40	97 ± 17	0.184
HbA1c (%)	6.3 ± 1.2	6.2 ± 0.62	0.620
Uric acid (mg/dl)	6.8 ± 1.2	7.6 ± 1.1	0.611
Albumin (mg/dl)	4.2 ± 0.2	4.5 ± 0.6	0.070
Hemoglobin, (g/dL)	13 ± 1.4	14 ± 1.5	0.340
Platelet count (10 ³ /μL)	283 ± 64	271 ± 72	0.267
WBC count, (10 ³ /μL)	8.9 ± 11	11 ± 14	0.568
Riser pattern group n (%)	9(10)	7(7)	0.405
Non-dipper pattern group n (%)	45(49)	43(45)	0.502
Dipper pattern group n (%)	32(28)	38(40)	0.280
Extreme dipper pattern group n (%)	5(7)	7(8)	0.730
Systolic BP (total) (mmHg)	126 ± 18	132 ± 17	0.038
Diastolic BP (total) (mmHg)	83 ± 12	87 ± 9	0.920
Average BP (total) (mmHg)	96 ± 11	98 ± 11	0.189
Pulse pressure (total) (mmHg)	47 ± 12	49 ± 11	0.214
Heart rate (total) (beats/min.)	77 ± 11	74 ± 9	0.085
Systolic BP (awake) (mmHg)	131 ± 17	134 ± 15	0.234
Diastolic BP (awake) (mmHg)	84 ± 9.5	85 ± 9.8	0.380
Average BP (awake) (mmHg)	99 ± 11	101 ± 11	0.257
Pulse pressure (awake) (mmHg)	46 ± 9.8	48 ± 10	0.151
Heart rate (awake) (beats/min.)	89 ± 18	78 ± 10	0.232
Systolic BP (sleep) (mmHg)	121 ± 20	123 ± 20	0.600
Diastolic BP (sleep) (mmHg)	77 ± 12	76 ± 10	0.856
Average BP (sleep) (mmHg)	91 ± 13	91 ± 12	0.530
Pulse pressure (sleep) (mmHg)	46 ± 12	47 ± 11	0.582
Heart rate (sleep) (beats/min.)	70 ± 11	68 ± 12	0.379
QRS, ms	87 ± 10	89 ± 11	0.089
QT, ms	354 ± 32	357 ± 35	0.461
QTc, ms	399 ± 21	401 ± 19	0.609
QTd, ms	38.7 ± 4.9	39.9 ± 5.6	0.100
Tpe, ms	71 ± 6.4	73 ± 6.6	0.123
P dispersion	31.4 ± 5.5	31.8 ± 5.9	0.549
f(QRS-T) (°)	21 ± 16	51 ± 30	<0.001

Data presented as mean ± standard deviation or number (%) of patients. Abbreviations: HDL: high-density lipoprotein, LDL: low-density lipoprotein; WBC: white blood cells; QTc: Corrected QT interval; f(QRS)-T: Frontal QRST angle; QTd: QT dispersion; BP: blood pressure; MBPS: morning blood pressure surge

Laboratory measurements

Prior to the start of the study, the patients were informed about the procedure. Following a 12-hour fasting, blood samples were taken from the antecubital vein after the outpatient clinical examination. Basal creatinine level, white blood cell count, platelet count, hemoglobin concentration, lipid profile, glucose, uric acid and other biochemical parameters were measured using standard techniques.

Statistical analysis

SPSS 15.0 (SPSS for Windows 15.0, Chicago, IL) was used for statistical evaluation of the data. Kolmogorov–Smirnov test was used for detecting normality of distribution. The data were expressed as mean $\pm$ SD for continuous variables and percentage for categorical variables. Chi-square test was used for categorical variables and Students t-test was used for continuous variables while evaluating the differences between groups. To estimate the risk of MBPS and to determine the optimal cutoff point of the f(QRS-T) angle, receiver operating characteristic (ROC) curve was generated with which point sensitivity and specificity were determined according to Youden J index. Multivariate linear analysis was used to assess associations of the f(QRS-T) angle with potential confounders via a multivariate linear regression model based on previous studies (12,17,27). Statistical significance was accepted as $p < .05$.

Reproducibility

To describe the intra-observer variability, 15 subjects were casually selected from the study group, and the measurements were repeated under the same basal conditions. The reproducibility of the repolarization parameters obtained by electrocardiography was assessed with the coefficient of variation between the measurements. The intra-observer variability was 1.0% for the f(QRS-T) angle and 5.5% for the Tpe interval.

Results

A total of 186 newly diagnosed HT patients who met the inclusion criteria were included in the study. The mean age of these patients was 52.4 years and 54% were female. Patients were evaluated according to their ABPM results. The clinical and demographic characteristics of Group I and Group II patients separated according to MBPS ($>$ or <37 mm Hg) values are given in Table 1. No significant differences could be identified between the groups except for age and the f(QRS-T) angle. The average f(QRS-T) angle in Groups I and 2 was $21^\circ \pm 16^\circ$ and $51^\circ \pm 30^\circ$, respectively ($P < .001$). Other repolarization parameters and clinical characteristics were similar between the groups.

To evaluate the effect of the f(QRS-T) angle on clinical variables, the median value was accepted as 31° . The clinical and demographic characteristics of Group I and Group II patients groups divided according to the f(QRS-T) angle ($<$

or $\geq 31^\circ$) are given in Table 2. Age and gender were similar between the two groups. In our study, no relationship was found between the f(QRS-T) angle and non-dipper hypertension ($P = .495$). The MBPS was found to be 26 mm Hg $\pm$ 9.5 mm Hg and 40 mm Hg $\pm$ 10.6 mm Hg in Groups I and II, respectively; this difference was statistically significant ($P < .001$).

Based on previous studies (12,17,27) and our own data, univariate and multivariate regression analysis was performed for factors that can affect the f(QRS-T) angle such as age, ejection fraction, systolic BP (total), pulse pressure (total), QTd, Tpe and MBPS (Table 3). In the univariate regression analysis, all parameters except ejection fraction and pulse pressure affected the f(QRS-T) angle. When these parameters affecting the f(QRS-T) angle in univariate analysis were evaluated by multivariate regression analysis, Tpe and MBPS were found to be independent predictors of the f(QRS-T) angle.

A receiver operating characteristic (ROC) analysis was performed with the f(QRS-T) angle for predicting MBPS in newly diagnosed hypertensive patients. The QRS-T angle was found to be a powerful predictor of MBPS (AUC: 0.883; 95% CI: 0.83–0.93; $p < .001$; cutoff value: 33.5; sensitivity: 83%; specificity: 80%) (Figure 2).

Discussion

In the current study, the f(QRS-T) angle was found to be significantly higher in the high-value MBPS group compared to the low-value MBPS group. Additionally, according to a multivariate regression analysis, a significant association was identified between a high f(QRS-T) angle and high-value MBPS. Moreover, a high-value of MBPS could predict a higher f(QRS-T) angle with high sensitivity and specificity. To our knowledge, the present study is the first in the literature to evaluate the relationship between the f(QRS-T) angle and exaggerated MBPS in newly diagnosed treatment-naïve HT patients.

Various studies have shown that adverse cardiovascular events including acute coronary syndromes, sudden cardiac death and stroke occur more frequently in the morning hours (24,30,31). An activation of the sympathetic nervous system has been implicated in the development of MBPS (30,32). Marfella et al. found that sympathetic hyperactivity and deterioration in electrocardiographic repolarization parameters coexisted in patients with exaggerated MBPS (32). Although MBPS is considered to be physiologically normal in healthy individuals, exaggerated MBPS is a pathological condition that is associated with advanced age as well as several diseases such as HT, diabetes mellitus and smoking (24,30,31). Additionally, endothelial dysfunction was seen more frequently in patients with exaggerated MBPS (33). The association between exaggerated MBPS and poor cardiac outcomes may be linked to early morning changes in multiple systemic circulatory parameters such as BP, heart rate, activity of the autonomic nervous system or the renin-angiotensin cascade (20). Ventricular

Table 2. Comparison of the patient data according to the f(QRS-T) angle.

Variables	Group I: f(QRS-T) <31° (n = 81)	Group II: f(QRS-T) ≥31° (n = 105)	P value
Age (years)	48.1 ± 15.7	52.4 ± 14.8	0.060
Female gender, n (%)	54(66)	47(44)	0.136
Diabetes mellitus, n (%)	13 (16)	10 (9)	0.608
Hyperlipidemia, n (%)	29 (28)	44(41)	0.398
Height (cm)	163 ± 10	163 ± 8	0.790
Weight (kg)	77 ± 14	79 ± 15	0.257
Body mass index	28 ± 5.1	29 ± 4.2	0.477
Heart rate (beats)	78 ± 12	79 ± 14	0.857
Ejection fraction (%)	66 ± 2.3	65 ± 2.6	0.496
Total cholesterol (mg/dl)	191 ± 49	200 ± 38	0.243
HDL cholesterol (mg/dl)	45 ± 9.6	48 ± 13.5	0.095
LDL cholesterol (mg/dl)	120 ± 30	125 ± 32	0.482
Triglycerides (mg/dl)	154 ± 74	173 ± 174	0.493
Creatinine (mg/dl)	0.82 ± 0.76	0.76 ± 0.19	0.463
Glucose (mg/dl)	100 ± 34	101 ± 30	0.921
HbA1c (%)	6.6 ± 1.3	6.1 ± 0.52	0.119
Uric acid (mg/dl)	7.8 ± 14	5.3 ± 1.4	0.441
Albumin (mg/dl)	4.3 ± 0.3	4.3 ± 0.3	0.676
Hemoglobin, (g/dl)	13 ± 1.4	14 ± 1.5	0.453
Platelet count (10 ³ /μL)	284 ± 69	269 ± 65	0.161
WBC count (10 ³ /μL)	8.2 ± 10	10 ± 12	0.396
Riser pattern group n (%)	7 (4)	9(9)	0.652
Non-dipper pattern group n (%)	36 (49)	52(49)	0.103
Dipper pattern group n (%)	32(40)	38(29)	0.242
Extreme dipper pattern group n (%)	6 (7)	6(6)	0.951
Systolic BP (total) (mmHg)	126 ± 18	130 ± 16	0.073
Diastolic BP (total) (mmHg)	81 ± 10	83 ± 11	0.149
Average BP (total) (mmHg)	95 ± 11	99 ± 10	0.069
Pulse pressure (total) (mmHg)	46 ± 11	49 ± 12	0.233
Heart rate (total) (beats/min.)	76 ± 12	75 ± 9	0.730
Systolic BP (awake) (mmHg)	130 ± 17	135 ± 15	0.070
Diastolic BP (awake) (mmHg)	83 ± 9	86 ± 9	0.088
Average BP (awake) (mmHg)	98 ± 11	102 ± 10	0.059
Pulse pressure (awake) (mmHg)	46 ± 9	48 ± 10	0.098
Heart rate (awake) (beats/min.)	79 ± 11	86 ± 17	0.444
Systolic BP (sleep) (mmHg)	121 ± 19	123 ± 21	0.357
Diastolic BP (sleep) (mmHg)	75 ± 10	78 ± 12	0.083
Average BP (sleep) (mmHg)	89 ± 13	93 ± 12	0.101
Pulse pressure (sleep) (mmHg)	45 ± 11	48 ± 12	0.218
Heart rate (sleep) (beats/min.)	70 ± 12	68 ± 15	0.400
QRS, ms	86 ± 9	90 ± 11	0.028
QT, ms	366 ± 32	366 ± 35	0.961
QTc, ms	399 ± 21	400 ± 20	0.711
QTd, ms	38 ± 5.2	40 ± 5.2	0.030
Tpe, ms	71 ± 6.2	73 ± 6.5	0.054
P dispersion	31 ± 5.2	32 ± 5.9	0.375
MBPS	26 ± 9.5	40 ± 10.6	<0.001

Data presented as mean ± standard deviation or number (%) of patients. Abbreviations: HDL: high-density lipoprotein; LDL: low-density lipoprotein; WBC: white blood cells; QTc: Corrected QT interval; f(QRS)-T: Frontal QRS-T angle; QTd: QT dispersion; BP: blood pressure; MBPS: morning blood pressure surge

Table 3. Univariate and multivariate linear regression analysis of f(QRS-T) angle to other study variables.

Variable	Univariate (β)	P value	Multivariate (β)	P value
Age	0.148	0.045		
Ejection fraction	-0.128	0.122		
Systolic BP (total)	0.147	0.042		
Pulse pressure (total)	0.090	0.230		
QTd	0.184	0.033		
Tpe	0.171	0.020	0.125	0.015
MBPS	0.612	<0.001	0.603	<0.001

Abbreviations: Tpe: T peak-end; f(QRS)-T angle: frontal QRST angle; QTd: QT dispersion; BP: blood pressure; MBPS: morning blood pressure surge

arrhythmias including ventricular tachycardia and ventricular fibrillation also tend to occur in the morning hours (34,35). Harbalioglu et al. reported that MBPS was associated with severe coronary artery disease in hypertensive patients (6). These data highlight the importance of MBPS in hypertensive patients. Yano et al. (28). showed that MBPS in patients treated with antihypertensive agents was significantly associated with cardiovascular remodeling, independently of 24 hours' blood pressure variability. These results of the study showed that MBPS changed ventricular remodeling independently of blood pressure variability. As a result of MBPS, repolarization parameters are affected due to the developing remodeling.

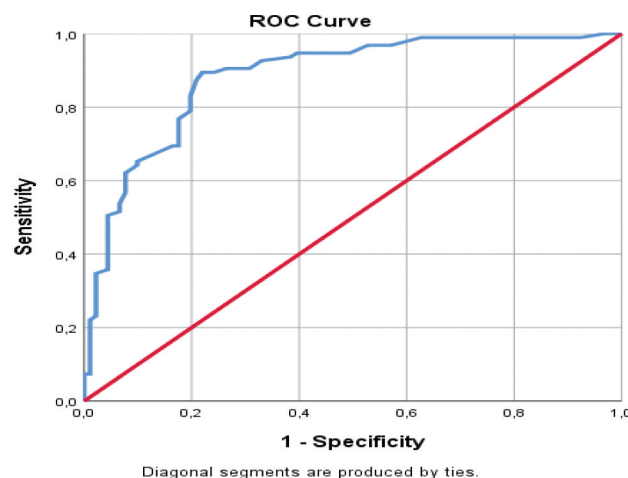
The f(QRS-T) angle is considered to be a new marker of heterogeneity in myocardial depolarization and repolarization. It is calculated as the angle between depolarization and repolarization axes (16,29). Two types of QRS-T angles can be calculated: three-dimensional and two-dimensional. The three-dimensional QRS-T angle (spatial QRS-T angle) is used less often due to a more complex calculation method. The two-dimensional angle (frontal QRS-T angle) is used more frequently because it is easier to calculate and apply (15). In addition, the risk estimation power of the three-dimensional and two-dimensional QRS-T angles are similar (18). Therefore, the two-dimensional QRS-T angle (frontal QRS-T angle) was determined in the current study.

The f(QRS-T) angle has been associated with different clinical situations and is a useful new parameter in determining

ventricular heterogeneity, fibrosis, and increased risk of arrhythmias (15,36). Ventricular depolarization and repolarization aspects are generally similar. Therefore, the f(QRS-T) angle is usually narrow (27). An enlargement of this angle suggests a perturbation in the depolarization and repolarization phases and may trigger the development of arrhythmia (1). Ventricular malignant arrhythmias usually occur in the morning hours, and MBPS in hypertensive patients is significantly associated with adverse events (30). Therefore, measurement of the f(QRS-T) angle can aid the clinician in determining the treatment protocol and precautions.

Regardless of how it is measured, the QRS-T angle varies depending on age and gender. In females, the QRS-T angle is narrower than in males, and the QRS-T angle widens as the age increases, regardless of gender (15). In the current study, the age and gender distribution of the study cohort was found to be proportional. Nonetheless, the QRS-T angle showed an increase based on age and gender. Tanrıverdi et al. found the relationship between non-dipper hypertension and the f(QRS-T) angle in patients with no hypertrophy (17). In our study, however, no relationship could be found between the f(QRS-T) angle and non-dipper hypertension.

The current study with its prospective design significantly adds to the current literature in establishing a relationship between the f(QRS-T) angle and MBPS. However, the low number of patients participating in the study and the lack of long-term follow-up for adverse events are important



	C- Statistics	95%Confidence interval	P value	Cut-off value	Sensitivity	Specificity
f(QRS-T)	0.883	0.83-0.93	<0.001	33.5	83%	80%

Figure 2. Receiver operating characteristic (ROC) curve of the f(QRS-T) angle for predicting an exaggerated morning blood pressure surge.

limitations of the study. Long-term follow-up studies with larger patient populations are needed.

Conclusion

The current study demonstrated a significant association between MBPS and the f(QRS-T) angle, which may predict adverse outcomes in patients diagnosed with hypertension. HT patients who have a wide f(QRS-T) angle may benefit from awareness of MBPS and planning of the treatment protocol; however, more comprehensive studies are needed to strengthen this theory. The results of the current study show that the f(QRS-T) angle can be used to predict the risk of MBPS in hypertensive patients.

Statement of responsibility

The authors have access to all data and shared all responsibility. All authors have reviewed and accepted the content of the article. Ethics committee approval for the study was obtained from Süleyman Demirel University Ethics Committee with the number 72867572-050.01.04-75201-15/05/2020.

Author's contribution

AB: study concept, design, data collection, drafting the manuscript; FA: data collection, design, drafting the manuscript, critical revision; HAB: analysis and interpretation of data; İBI: design, analysis and interpretation of data; FA: design, drafting the manuscript; HO: Statistical analysis

Declaration of Conflicting Interests

The authors declare that they have no conflict of interest

Disclosure of potential conflicts of interest

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