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The Effect of Electroconvulsive Therapy on Frontal QRS-T Angle in Psychiatric Patients

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ABSTRACT

Introduction: Electroconvulsive therapy (ECT) is one of the biological therapies that is well tolerated and has a low risk of complications. Acute cardiovascular complications related to ECT such as ventricular arrhythmia, myocardial infarction and cardiac arrest have been recorded. Increased frontal QRS-T (fQRS-T) angle was associated with ventricular arrhythmia, sudden cardiac death and total mortality. In this study, we aimed to evaluate the effect of ECT on the myocardium using electrocardiography (ECG) parameters such as fQRS-T angle, QRS duration, QT and QTc interval.

Methods: A total of 108 patients diagnosed with bipolar disorder (n=36), depressive disorder (n=70) and schizophrenia (n=2) who underwent ECT were included in this study. 12-lead surface ECG of all patients were taken before the ECT, 15 min. after ECT and 24 hour after ECT.

Results: QRS duration, QT interval and corrected QT (QTc) interval were not changed significantly during the follow-up period. However, we found that, fQRS-T angle was significantly increased 15 minutes after ECT compared to baseline angle ($p<0.001$). We also detected that this increase in fQRS-T angle 15 minutes after ECT was significantly reduced 24 hours after ECT ($p=0.031$). Meanwhile, there was no significant difference between baseline and 24th hour fQRS-T angle ($p=0.154$).

Conclusions: In our study, a significant increase in fQRS-T angle was observed 15 min after ECT. However, the fQRS-T angle was found to return to normal after 24 hours. Our findings may indicate that ECT does not have a permanent side effect on the risk of cardiovascular events according to the fQRS-T angle.

Keyword: Cardiovascular side effect, electrocardiography, electroconvulsive therapy, frontal QRS-T angle

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INTRODUCTION

Electroconvulsive therapy (ECT) is one of the biological therapies that is well tolerated and has a low risk of complications (1). ECT-related cardiovascular complications have been reported in the literature. Acute cardiovascular complications related to ECT such as ventricular arrhythmia (2), myocardial infarction (3), pulmonary embolism (4), takotsubo cardiomyopathy (5) and cardiac arrest (2) have been recorded.

Alteration in myocardial depolarization and repolarization has a crucial role in the development of cardiac arrhythmias, sudden cardiac death and cardiovascular mortality (6). Frontal QRS-T (fQRS-T) angle, defined as the absolute difference between the repolarization and depolarization vectors of the ventricle, is a novel marker of ventricular depolarization and repolarization heterogeneity (7). Recent studies have shown that the fQRS-T angle is one of the electrocardiographic (ECG) parameters indicating increased cardiovascular mortality (7). Also, increased fQRS-T angle has been related with ventricular arrhythmia, sudden cardiac death, cardiovascular mortality and total mortality (8). In a study conducted with schizophrenia patients, it was reported that the fQRS-T angle was significantly increased compared to healthy controls and this may be helpful in cardiovascular risk assessment (9).

Highlights

- **Frontal QRS-T angle is a novel marker of ventricular repolarization.**
- **A significant increase was observed in fQRS-T angle 15 min after ECT in our study.**
- **This increase in fQRS-T angle was returned to normal value 24 hours after ECT.**
- **We suggest that ECT does not have a permanent cardiovascular risk.**

When the literature was reviewed, it was observed that only one study examined the relationship between ECT and QRS-T angle. In this study, Próchnicki et al. evaluated the effect of ECT on spatial QRS angle. They found that spatial QRS angle after 1 hour of ECT did not reveal any significant increase compared to the baseline value (10). They concluded no negative effects of ECT on the risk of adverse cardiovascular events. However, the

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number of patients in this study is quite small (n=44) and it was suggested that it is essential to continue studies to evaluate the safety of ECT.

In our study, we aimed to evaluate the effect of ECT on myocardium using ECG parameters such as fQRS-T angle, QRS duration, QT interval and QTc interval during the follow-up of ECT patients. We hypothesized that ECT may affect the frontal QRS-T angle, QRS duration, QT interval and QTc interval by altering the myocardial depolarization and repolarization.

METHODS

Study Population

The study included 60 women and 48 men diagnosed with bipolar disorder (n=36), depressive disorder (n=70) and schizophrenia (n=2) in the psychiatry department of Harran University Medical Faculty Hospital. Patients aged between 18 and 62 years were included in the study. Indications for ECT treatment were acute deterioration of mental status requiring emergency and effective treatment, drug resistance and a history of good response to previous ECT treatment. Participants were informed about the study before ECT. Patients without informed consent were excluded. Patients with organic heart disease were not included in the study. In addition, patients with arrhythmias that were not in sinus rhythm and paced rhythm on baseline ECG were excluded.

Before starting ECT, a standard medical history was taken, patients were physically examined by an independent physician and an anesthesiologist, and all available medical data were reviewed. Comorbidities included obesity (n=40), type 2 diabetes mellitus (n=6), arterial hypertension (n=10) and nicotine dependence (n=31) (Table 1). All patients were receiving psychotherapy and pharmacotherapy and were taking antidepressants and/or antipsychotics and/or mood stabilizers.

Informed consent was obtained from all patients participating in the study. Necessary permission for the study procedures was obtained from the ethics committee of Harran University Medical Faculty Hospital with the approval number of 22.23.08 and dated 28.11.2022. Our study was conducted in compliance with the revised Helsinki Declaration criteria.

Electroconvulsive Therapy

Bilateral ECT procedures were performed on the patients using the Thymatron System IV (Somatics, LLC) device in a standard way (11). Propofol was administered as anaesthetic and rocuronium bromide as muscle relaxant. Electroencephalography monitoring was performed to confirm seizure occurrence. All ECT treatments analyzed in our study were effective and resulted in 30-second seizures. Patients' 1st ECTs were analyzed.

Electrocardiography

A total of 3 twelve-lead ECG recordings were obtained from all patients at least 10 minutes before ECT and 15 minutes and 24 hours after ECT in the supine position at rest with a paper speed of 25 mm/sec, a filter pitch of 0.16–100 Hz. and height of 10 mm/mV ECG evaluation was performed by two cardiologists. QT interval measurement was calculated with the help of magnifiers. fQRS-T angle, QRS duration, QT interval and QTc interval parameters were analyzed from the ECGs.

The distance from the beginning of the Q wave to the end of the T wave is the QT interval. QTc data was calculated using Bazett's formula (12). The fQRS axis and T axis calculations were made from the automatic report section of the ECG device. These angles were checked by the cardiologist. The fQRS-T angle was found by taking the absolute difference between the QRS axis and the T axis (fQRS-T angle=QRS axis – T axis). The measurement method of the fQRS-T angle obtained from the automatic report section of the surface ECG device is shown in Figure 1. If this angle exceeded 180°, it was recalculated by subtracting the current angle from 360° (7,8,13).

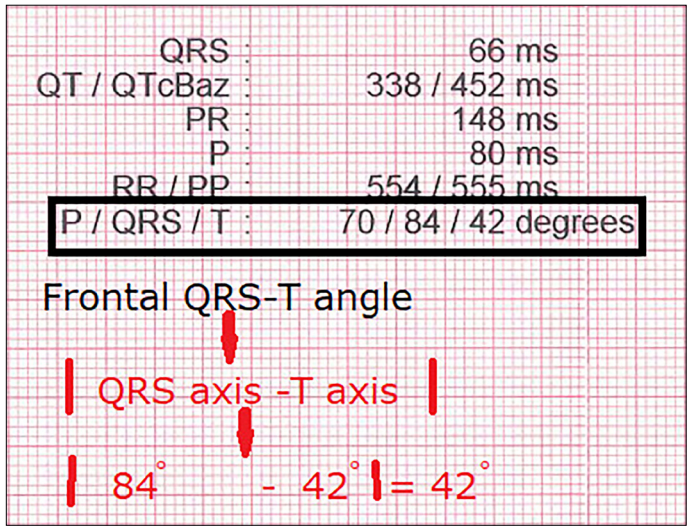

Figure 1. Measuring of the fQRS-T angle on the ECG.

Statistical Analyses

The IBM Statistical Package for Social Sciences (SPSS) program version 22 was used to evaluate all data. Kolmogorov-Smirnov test was used to evaluate whether continuous variables fit the normal distribution. Continuous variables were presented as mean ± standard deviation for parametric variables and median (interquartile range-IQR) for non-parametric variables. Categorical variables were presented as number and percentages. Independent sample t test was used for the comparison of two independent groups and one-way Analysis of variance (ANOVA) test was used for the comparison of more than two independent groups in parametric variables. Mann-Whitney U test was used for the comparison of two independent groups and Kruskal-Wallis test was used for the comparison of more than two independent groups in non-parametric variables. Repeated measures ANOVA was used for the comparison of repeated measurements in normally distributed variables. Friedman test with Bonferroni corrections was used for the comparison of repeated measurements in non-normally distributed variables. Categorical variables were analyzed with the chi-square test. $p<0.05$ value was accepted statistically significant.

RESULTS

In this study, a total of 108 patients (female 55.5%, male 44.5%) were included. The mean age of the patients was 35.5±12.0 years. Sociodemographic data and blood test values of the patients are shown in Table 1.

The comparison of all ECG data including before, 15 minutes after and 24 hours after ECT according to the diagnostic groups are shown in Table 2. There were no significant differences regarding QRS duration, QT interval, QTc interval and fQRS-T angle among the groups.

The comparisons of basal characteristics and ECG data according to gender are presented in Table 3. No statistically significant difference was found between female and male patients in terms of basal characteristics and fQRS-T angle. However, we found that basal and 15th minute QRS durations ($p=0.007$ and $p=0.017$, respectively) were significantly higher in male patients than in female patients.

Table 1. Sociodemographic data and blood test values of the study population

Variables	**n=108**
Age, years	35.5±12.0
Female/Male sex, number	60/48
Body mass index kg/m^2	28.7±5.9
Systolic blood pressure, mmHg	116.25±10.52
Diastolic blood pressure, mmHg	73.66±8.82
Hypertension, n (%)	10 (9.25)
Diabetes mellitus, n (%)	6 (6.48)
Current smoking, n (%)	31 (28.7)
Creatinine, mg/dL	0.78±0.18
Sodium mEq/L	139.54±3.13
Potassium mEq/L	4.3±0.34
Calcium mEq/L	9.29±0.39
Magnesium	1.95±0.22
C-reactive protein, mg/dL	0.39±0.51
TSH, mIU/L	1.94±1.00
Hemoglobin, g/dl	13.75±1.71
WBC, cells/ml	8.25±2.57
Platelet, cells/ml	13.75±1.71

TSH: Thyroid stimulating hormone; WBC: White blood cell.

Table 2. Electrocardiographic data before ECT, 15 minutes after ECT and 24 hours after ECT according to diagnostic groups

Parameters		**Depressive disorder (n=69)**	**Bipolar disorder mania (n=27)**	**Bipolar disorder depression (n=9)**	**Schizophrenia (n=2)**	**p**
Before ECT	QRS duration, ms	89.04±13.20	97.33±29.38	85.33±10.19	76.00±0.80	0.116*
	QT interval, ms	363.04±40.79	358.29±39.11	373.11±29.81	340.00±10	0.436*
	QTc interval, ms	404.82±19.26	408.22±21.44	412.11±8.68	378±8	0.523*
	Frontal QRS-T angle, (°)	19 (7–34)	13 (9–42)	26 (12–45.5)	13 (13–13)	0.657ᶻ
15 min. after ECT	QRS duration, ms	90.00±14.73	91.33±9.44	84.66±13.11	78.10±12.10	0.665*
	QT interval, ms	365.55±32.71	351.40±29.80	373.77±36.66	355.70±22.20	0.092*
	QTc interval, ms	406.32±20.52	404.32±20.52	421.22±26.07	395.20±6.9	0.737*
	Frontal QRS-T angle, (°)	27.5(17.75–53.25)	47(15–65)	25(62–11)	90(85–95)	0.161ᶻ
24 hr. after ECT	QRS duration, ms	90.29±16.38	90.56±13.17	84.00±10.86	80.00±0	0.129*
	QT interval, ms	357.61±51.06	350.80±29.60	368.00±16.15	342.00±0	0.096*
	QTc interval, ms	408.27±20.52	399.60±26.70	405.77±9.45	382.0±0	0.150*
	Frontal QRS-T angle, (°)	24(14–31.5)	17(4–29)	19(18–29.5)	15(15–15)	0.495ᶻ

ECT: Electroconvulsive therapy; QTc: Heart rate-corrected QT interval; *: One way ANOVA test, ᶻ: Kruskal-Wallis test.

Electrocardiographic data before ECT, 15 minutes after ECT and 24 hours after ECT are shown in Table 4. QRS duration (p=0.339), QT interval (p=0.279) and QTc interval (p=0.804) had not changed significantly during the follow-up period. However, it was detected that fQRS-T angle had significantly changed during the follow-up period (p<0.001) (Table 4). The post hoc analyses are demonstrated in Figure 2. When compared to baseline angle, fQRS-T angle had significantly increased 15 minutes after ECT (from 18 [9–34] to 29.5 [17–60.8], p<0.001). However, we also detected that this increase in fQRS-T angle 15 minutes after ECT had significantly reduced 24 hours after ECT (from 29.5 [17–60.8] to 22 [12.5–30], p=0.031). Meanwhile, there was no significant difference between baseline and 24th hour fQRS-T angle (p=0.154).

Table 3. Comparison of electrocardiographic data before ECT, 15 minutes after ECT and 24 hours after ECT and cardiovascular risks by gender

Parameters		Female (n=60)	Male (n=48)	p
Age, years		34.05±11.33	37.45±12.73	0.145$^{\alpha}$
BMI, kg/m^2		29.35±6.26	27.92±5.45	0.214$^{\alpha}$
HT (%)		4 (6.7)	6 (12.5)	0.334$^{\beta}$
DM (%)		2 (3.3)	4 (8.3)	0.403$^{\beta}$
Before ECT	QRS duration, ms	86.23±13.23	95.91±22.86	**0.007**$^{\alpha}$
	QT interval, ms	364.16±35.43	360.08±43.57	0.594$^{\alpha}$
	QTc interval, ms	405.76±22.43	405.83±15.12	0.895$^{\alpha}$
	Frontal QRS-T angle, (°)	18 (10–35)	16.5(8.25–32)	0.861$^{\delta}$
15 min. after ECT	QRS duration, ms	87.10±15.92	93.39±8.27	**0.017**$^{\alpha}$
	QT interval, ms	355.34±34.98	371.73±27.48	0.055$^{\alpha}$
	QTc interval, ms	404.20±23.22	410.69±17.30	0.118$^{\alpha}$
	Frontal QRS-T angle, (°)	28.5(15.5–55.75)	32(18–66.5)	0.638$^{\delta}$
24 hr. after ECT	QRS duration, ms	87.73±17.97	92.18±9.70	0.140$^{\alpha}$
	QT interval, ms	361.90±37.79	349.31±51.04	0.152$^{\alpha}$
	QTc interval, ms	407.51±23.45	402.68±18.97	0.264$^{\alpha}$
	Frontal QRS-T angle, (°)	24.5(14–30)	20(10–42.5)	0.658$^{\delta}$

BMI: Body mass index; DM: Diabetes mellitus; ECT: Electroconvulsive therapy; HT: Hypertension; QTc: Heart rate-corrected QT interval; $^{\alpha}$: Student t test; $^{\beta}$: Chi-Square Test; $^{\delta}$: Mann-Whitney U Test.

Table 4. Electrocardiographic data at before ECT, 15 minutes after ECT and 24 hours after ECT

Parameters	Before ECT	15 min. after ECT	24 hr. after ECT	p value
QRS duration, ms	90.76±18.97	89.55±13.05	89.72±15.37	0.339$^{¥}$
QT interval, ms	363.55±39.36	361.76±31.82	357.64±44.58	0.279$^{¥}$
QTc interval, ms	406.73±19.15	406.69±20.71	406.27±21.75	0.804$^{¥}$
Frontal QRS-T angle, (°)	18 (9–34)	29.5 (17–60.8)	22 (12.5–30)	**<0.001**$^{\#}$

ECT: Electroconvulsive therapy; QTc: Heart rate-corrected QT interval; $^{¥}$: Repeated Measure ANOVA test; $^{\#}$: Friedman test.

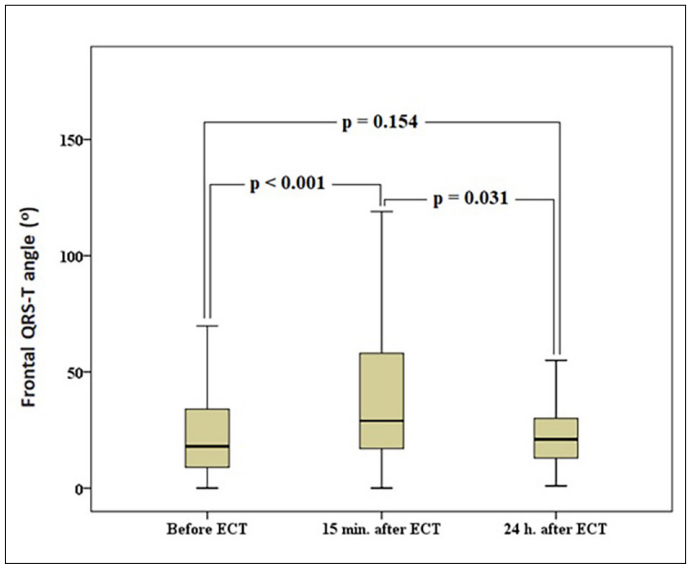

Figure 2. Frontal QRS-T angle measurements before ECT, 15 min. after ECT and 24 h. after ECT.

DISCUSSION

In our prospective cohort study involving 108 patients who underwent ECT, a significant increase in the fQRS-T angle was observed after ECT. However, it was understood that the fQRS-T angle returned to normal in the follow-up after 24 hours.

There are several concerns about the safety of ECT on the cardiovascular system (14). In the application of electrical stimulation during ECT, there is a vagal stimulus that causes a parasympathetic surge. This stimulus causes hypotension, decrease in heart rate (HR) and sometimes transient asystole. This asystole and bradycardia is quite common. In one study, the incidence of asystole of 5 seconds or more was reported to be 40.1%. The initial parasympathetic surge is followed by a sympathetic surge causing hypertension and tachycardia (15). One study found that both blood pressure and HR increased (16). Most of the time, these transient increases in blood pressure and HR are well tolerated. However, some patients may experience myocardial ischemia due to increased cardiac output (15). In the literature, it has been shown that approximately 5 to 10% of patients receiving ECT develop cardiac troponin elevation, indicating myocardial cell damage (17,18). Of course, the cardiac effects of ECT are short-term and these effects end after a while (19–21).

In patients with pre-existing cardiovascular conditions, brief but severe hemodynamic stress resulting from seizure initiation during ECT may increase the risk of cardiovascular events (19,22). The mortality rate of ECT was 0.42 per 1000 patients and 29% of these deaths were found to be cardiac-related. This study also showed that major adverse cardiac effects developed after ECT at a rate of 2% (23).

It is known that some changes occur on the parasympathetic and sympathetic system dur to the electric current given in ECT (14). The depolarization and repolarization mechanisms of the heart are disrupted due to these systems activated by this electric current. Cardiac complications may occur due to these effects of ECT. Despite the rapid development of the diagnosis of cardiological diseases, ECG is still the most important parameter in the diagnosis and prognosis of these diseases (24). QTc, QTd, JTc, JTd, Tp-e interval and Tp-e/QTc ratio, which are considered to be potential repolarization markers in previous studies, were studied in patients receiving ECT (25). However, the fact that most of these parameters are affected by heart rate has led researchers to work on new ECG parameters (24,26). The fQRS-T angle is calculated by subtracting the QRS with ventricular depolarization from the T wave indicating ventricular repolarization and is thought to be a better parameter indicating ventricular repolarization (27). In addition, since the fQRS-T angle is not affected by both the automatic calculation of the ECG device and the heart rate, it is more practical to use in situations where the heart rate changes, such as ECT.

In existing reports on ECT, several ECG parameters have been studied, most commonly the QT interval, QTc interval and its distribution. It should be highlighted that the literature findings are not consistent (10). Masdrakis et al. reported data from 9 patients being treated with ECT, with no QTc prolongation on ECG or adverse cardiovascular events (28). Próchnicki et al. evaluated the effect of ECT on ECG parameters. They found that QRS duration and QTc interval after 1 hour of ECT did not reveal any significant increase compared to the baseline value (10). We also analyzed ECG data in detail in our study. Similar to these studies, we found no significant change in QRS duration, QT interval, QTc interval values at before ECT, 15 minutes after ECT and 24 hours after ECT. In this study, we also compared the ECG data according to gender and found that basal and 15th minute QRS durations were significantly higher in male patients than in female patients. When we checked the literature, we detected that adult women have a smaller left ventricular mass and a narrower QRS duration, on average 10 ms shorter than men (29,30). It is probably the male hormones that cause this result. Our results were consistent with the literature when analyzed according to gender.

Although previous studies investigated the effect of ECT on QRS duration, QT and QTc interval, to our knowledge, no study evaluated the effect of ECT therapy on fQRS-T angle. In our study, we showed that the fQRS-T angle, which was previously associated with cardiac mortality and total mortality, increased significantly at 15th minute after ECT in patients who underwent ECT and we also found that the fQRS-T angle normalized compared to baseline on ECG taken 24 hours later. This suggests that there is an increase in cardiac risk in patients undergoing ECT in the acute period. However, fQRS-T angle returning to normal at the 24th hour after ECT may show us that there is no increase in cardiac risk due to ECT in the long term. Therefore, we believe that patients undergoing ECT should be closely monitored in the acute period in terms of arrhythmias.

Our research has certain limitations. Firstly, our study was a single-center study and there is no control group. The included patients were relatively young patients without a diagnosis of cardiovascular disease. Therefore, our results may be underestimated in the high cardiovascular risk group. Secondly, we performed two ECG assessments 15 minutes and 24 hours after ECT, which may not be sufficient to assess cardiovascular risk. Continuous and long-term ECG monitoring may help clarify the temporal relationship between ECT and arrhythmia. Thirdly, although the study patients were examined by an anaesthesiologist with ECG-guided physical examination before ECT, not all patients underwent routine echocardiography or exercise testing, which may result in an underestimation of the incidence of cardiovascular events. Finally, the study group received a single protocol anaesthesia (propofol and rocuronium bromide). Anaesthesia protocols based on other drugs should be evaluated separately.

Our findings suggest that, based on the fQRS-T angle, ECT has no lasting adverse effect on the risk of cardiovascular events. Because of the increased f QRS-T angle after ECT, it may be considered to follow these patients in the hospital for the first 24 hours in terms of cardiovascular risks. However, it is important to continue studies evaluating the long-term safety and complication risk of ECT in subgroups of patients with cardiovascular disease at baseline.

Ethics Committee Approval: Necessary permission for the study procedures was obtained from the ethics committee of Harran University Medical Faculty Hospital with the approval number of 22.23.08 and dated 28.11.2022.

Informed Consent: Informed consent was obtained from all patients participating in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept- ÜAF, HF; Design- ÜAF, HF; Supervision- ÜAF, HF; Resource- ÜAF, HF; Materials- ÜAF, HF; Data Collection and/or Processing- ÜAF, HF; Analysis and/or Interpretation- ÜAF, HF; Literature Search- ÜAF, HF; Writing- ÜAF, HF; Critical Reviews- ÜAF, HF.

Conflict of Interest: The authors declared that there is no conflict of interest.

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