Investigation of Electrocardiography Changes and, Specifically, Changes in the TpTe Interval and TpTe/QT Ratio in Patients Presenting with Electrical Injuries

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Abstract

Aim: The purpose of this study was to examine changes in cardiac monitoring, electrocardiography (ECG), or cardiac enzymes and, specifically, changes in the TpTe interval and TpTe/QT ratio in patients who presented with electrical injuries.

Materials and Methods: All patients aged over 18 years who had visited the Emergency Medicine Clinic between January 2011 and January 2014 because of electrical injuries and who were monitored for more than 24 h were included.

Results: Seventy patients were included in the trial. ECG changes were present in 19 patients (27.1%) at various time points (0th, 6th, 12th, and 24th hour). The TpTe intervals of the patients at the time points were 64.5 (IQR: 21.25), 65 (IQR: 21.5), 64 (IQR: 20), and 64 (IQR: 20) ms, respectively, which were within the normal range. Although a statistical difference was present (p=0.033), superior analyses showed no significant difference among the groups. The TpTe/QT ratios of the patients were 0.18 (0.07), 0.18 (0.05), 0.18 (0.06), 0.18 (0.05), respectively, which were within the normal range (p=0.105). We compared the TpTe intervals and TpTe/QT ratios of patients with and without ECG changes and found that no statistically significant difference was present at all time points. Besides this, no difference in the TpTe intervals and TpTe/QT ratios was identified between the groups with elevated and non-elevated troponin levels.

Conclusion: The use of TpTe intervals and TpTe/QT ratios may not be the correct approach for predicting potential rhythm disorders in electrical injuries. In addition, there is no association of the TpTe interval or the TpTe/QT ratio with ECG changes or troponin elevation caused by electrical injuries.
Keywords: Electrical injuries, electrocardiography, TpTe interval

Introduction

Electrical injuries (EIs) are associated with high morbidity and mortality and are a type of trauma that puts all age groups at risk (1). In the USA, more than 500 deaths are attributed to EIs annually (2). EIs can cause cardiac arrest, myocardial and valvular ruptures, structural changes in the coronary arteries, pericardial effusion, and various electrocardiography (ECG) changes. In most patients, at the very least, temporary ECG changes can be observed (3, 4). The purpose of our study was to investigate the epidemiologic characteristics of EIs, cardiac monitoring, ECG reports, and cardiac enzyme changes and, specifically, the TpTe and QT intervals and TpTe/QT ratio that develop in patients presenting with EIs.

Materials and Methods

Study population and study protocol

All patients who had visited the Emergency Medicine Clinic of Konya Training and Research Hospital between January 2011 and January 2014 because of EIs, who were monitored for more than 24 h, and who were over 18 years of age were included. This retrospective study was conducted by reviewing patient files. The cases were reviewed with regard to gender, age, location of EI, course of EI, and cause (low voltage or high voltage). Further, changes in ECG and cardiac enzymes, specifically, TpTe and QT intervals and the TpTe/QT ratio, and their association with rhythm disorders were investigated".

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The study protocol was approved by the Necmettin Erbakan University Faculty of the Medicine Ethics Committee and was conducted in accordance with the Declaration of Helsinki and Good Clinical Practice.

Electrocardiography measurement

The ECG records of the patients at baseline (0 h) and at 6, 12, and 24 h were evaluated. The Nihon Kohden ECG 1250 Cardiofax S (2009, Tokyo, Japan) device was used for recording ECGs. Records were obtained at a speed of 25 mm/s and with an amplitude of 10 mm/mV. The ECG records were at 800-dpi resolution and were measured by two specialists uninformed about the patient's conditions and with the help of a computer. The PR interval was measured as the distance from the start of the P wave to the start of the QRS complex (normal range of PR interval: 120–200 ms). A prolonged QRS duration was defined as ≥120 ms.

The TpTe interval was measured in precordial derivations by the "tail method." According to this, the distance between the projection of the T-wave's peak point on the isoelectric line and the end of the T wave was measured (normal range of TpTe: ≤85 ms) (5-7). The QT interval was measured as the distance between the start of the QRS complex and the end of the T wave (normal QT: 360–440 ms). In addition, in situations when the heart rate was not in a normal range, the corrected QT interval was calculated using Bazett's formula (7-10). This prevented abnormalities in the heart rate from affecting the TpTe/QT ratio (10). The TpTe/QT ratio was calculated after the TpTe interval was measured (11).

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS Inc.; Chicago, IL, USA) version 15.0 for Windows. Both visual (histogram and probability graphs) and analytical (Kolmogorov–Smirnov and Shapiro–Wilk tests) methods were used to determine if the data were normally distributed. Descriptive variables are expressed as the mean±SD for data normally distributed and as the median and interquartile range (IQR) for variables not normally distributed. Clinical and laboratory characteristics were evaluated via the Mann–Whitney U test for variables without normal distribution. For comparison of the differences among the groups, the Mann–Whitney U test was used for quantitative variables and the chi-square test was used for categorical variables. Hourly differences in the ECG parameters were evaluated via repeated measures analysis of variance for normally distributed variables, whereas variables without normal distribution were evaluated via the Friedman test. When necessary, the Wilcoxon test with the Bonferroni correction was used to compare variables. A p value of <0.05 was accepted as statistically significant with a 95% confidence interval.

Results

During the study period, 187 patients with EIs visited our clinic. Out of these patients, 45 were excluded because they were under the age of 18 years. In addition, 72 patients were excluded because they were monitored for less than 24 h. This left 70 patients who were included in the trial. The median age of the patients was 24 years (IQR: 22). The number of male patients was 55 (78.6%). Twenty-three patients (32.9%) were exposed to a high-voltage electrical current. When the Glasgow Coma Scores (GCSs) of the patients were reviewed on admission, 66 (94.3%) had a GCS of 15, while the remaining 4 (5.7%) had GCSs of 3, 6, 8, and 9. Eleven (15.7%) patients had elevated cardiac injury marker levels (troponin>0.2 ng/mL), while four (5.7%) had respiratory failure (need for endotracheal intubation and mechanic ventilation).

Table 1. 24-h ECG analysis of patients

ECG	At the 0th hour Number (n) (%)	At the 6th hour Number (n) (%)	At the 12th hour Number (n) (%)	At the 24th hour Number (n) (%)
NSR	55 (78.6)	63(90)	65 (92.9)	65 (92.9)
Sinus bradycardia	2 (2.9)	3 (4.3)	1 (1.4)	2 (2.9)
Sinus tachycardia	7 (10)	3 (4.3)	2 (2.9)	1 (1.4)
T-wave inversion	1 (1.4)	-	-	1 (1.4)
ST segment elevation	1 (1.4)	-	-	-
ST segment depression	1 (1.4)	-	1 (1.4)	-
Sinus arrhythmia	1 (1.4)	-	-	-
1st degree AV block	1 (1.4)	-	-	-
Ventricular fibrillation	1 (1.4)	-	-	-
Ventricular tachycardia	-	1(1.4)	-	-
Cardiac arrest	-	-	1 (1.4)	1 (1.4)
Total	70 (100)	70 (100)	70 (100)	70 (100)

ECG: electrocardiogram; NSR: normal sinus rhythm

Electrocardiography changes were present in 19 (27.1%) patients at various time points of the 24-hour ECG monitoring. The most common ECG change was identified as sinus tachycardia. Ventricular tachycardia (VT) and ventricular fibrillation (VF) occurred in one patient each. These patients were administered amiodarone and underwent electrical cardioversion, defibrillation, and cardiopulmonary resuscitation. Two (2.9%) of our patients died, and 68 (97.1%) were discharged from the hospital. The PR, QRS, QT, and TpTe intervals and the TpTe/QT ratio were evaluated at baseline and at 6, 12, and 24 h. The QT intervals of the 70 patients were 370 (IQR: 40), 380 (IQR: 35), 380 (IQR: 43.5), and 382 (IQR: 36) ms at baseline and at 6, 12, and 24 h, respectively, which were within normal ranges. No statistically significant difference was present (p=0.059). The TpTe intervals of the 70 patients were 64.5 (IQR: 21.25), 65 (IQR: 21.5), 64 (IQR: 20), and 64 (IQR: 20) ms at baseline and at 6, 12, and 24 h, respectively, which were within normal ranges. Although a statistically significant difference was apparent (p=0.033), the superior analysis showed no significant difference. The TpTe/QT ratio of the 70 patients were 0.18 (0.07), 0.18 (0.05), 0.18 (0.06), and 0.18 (0.05) at baseline and at 6, 12, and 24 h, respectively, which were within normal ranges. No statistically significant difference was shown (p=0.105). The details of these differences are shown in Tables 1 and 2. In addition, we compared the TpTe, QT intervals, and the TpTe/QT ratios in patients with and without ECG changes. The ECG records at baseline and at 6, 12, and 24 h were evaluated individually. There was no statistically significant difference among the groups at all time points (Table 3).

We compared the ECG changes and troponin elevation in patients with high- and low- voltage EIs. The median age of patients with high-voltage injuries was 28 years (IQR: 16), whereas that of

Table 2. Analysis of the ECG findings of the patients

ECG	Median value (IQR)				p
	At 0th hour	At 6th hour	At 12th hour	At 24th hour	
PR interval (ms*)	140 (23)	150 (23)	140 (28)	150 (20)	0.042
QRS distance (ms)	85 (20)	92 (20)	90 (19)	90 (20)	0.019[a]
QT interval (ms)	370 (40)	380 (35)	380 (43.5)	382 (36)	0.059
TpTe interval (ms)	64.5 (21.25)	65 (21.5)	64 (20)	64 (20)	0.033
TpTe/QT	0.18 (0.07)	0.18 (0.05)	0.18 (0.06)	0.18 (0.05)	0.105

Friedman Test; Wilcoxon signed-rank Test; [a]: The difference at 6 h from the first application of QRS distance. *ms: millisecond

Table 3. Comparing the TpTe intervals and TpTe/QT ratios of patients with and without ECG changes

	Patients with ECG changes (n: 19)	Patients with no ECG changes (n: 51)	p
First TpTe interval	71 (IQR: 27.5)	64.5 (IQR: 20)	0.622
TpTe interval at the 6th hour	65 (IQR: 21.5)	67 (IQR: 22)	0.973
TpTe interval at the 12th hour	63.5 (IQR: 20)	64 (IQR: 21)	0.591
TpTe interval at the 24th hour	63.5 (IQR: 20)	64 (IQR: 21)	0.591
First QT interval	386 (IQR: 46.3)	367 (IQR: 36)	0.400
QT interval at the 6th hour	377 (IQR: 54.5)	380 (IQR: 34)	0.753
QT interval at the 12th hour	380 (IQR: 50)	380 (IQR: 42)	0.612
QT interval at the 24th hour	388 (IQR: 46.3)	380 (IQR: 34)	0.676
First TpTe/QT	0.18 (IQR: 0.08)	0.18 (IQR: 0.06)	0.843
TpTe/QT at the 6th hour	0.19 (IQR: 0.07)	0.18 (IQR: 0.05)	0.946
TpTe/QT at the 12th hour	0.18 (IQR: 0.06)	0.18 (IQR: 0.06)	0.738
TpTe/QT at the 24th hour	0.17 (IQR: 0.05)	0.18 (IQR: 0.05)	0.618

Mann–Whitney U test, Interval: milliseconds.

patients with low-voltage injuries was 24 years (IQR: 22). No statistically significant difference in the ages of the patients in these two groups was shown (p=0.05). When genders of the patients in these two groups were compared, 23 males and no females were present in the high-voltage group, while 32 males and 15 females were present in the low-voltage group. A statistically significant difference in gender was present between the groups (p=0.001). High-voltage EIs were more common in males. ECG changes were identified in 10% of high-voltage EIs and 17.1% of low-voltage EIs. In addition, troponin levels were elevated in 8.6% of high-voltage EIs and in 7.1% of low-voltage EIs. No statistically significant difference in ECG changes and troponin level elevation was shown between the two groups (p=0.665 and p=0.095, respectively) (Table 4).

The median age of patients with elevated troponin levels was 26.5 years (IQR: 23.25) and 26 years (IQR: 21) in patients without elevated troponin levels. In the group with elevated troponin levels, there were 11 males and no females, while in the group without elevated troponin levels, there were 44 males and 15 females. The age and gender was compared in patients with elevated troponin levels caused by EIs and without elevated troponin levels, but no difference was seen (p=0.471 and p=0.105, respectively). However,

Table 4. Comparison of the ECG changes and troponin elevations in patients with high- and low-voltage EIs

	High-voltage EI (n: 23)	Lo- voltage EI (n: 47)	p
Age	28 (IQR: 16)	24 (IQR: 22)	0.05
Gender	M: 23; F: 0	M: 32; F: 15	0.001
ECG Changes	7 (10%)	12 (17.1%)	0.665
Troponin Elevation	6 (8.6%)	5 (7.1%)	0.095
	Patients with elevated troponin levels (n: 11)	Patients without elevated troponin levels (n: 59)	
Age	26.5 (IQR: 23.25)	26 (IQR: 21)	0.471
Gender	M: 11; F: 0	M: 44; F: 15	0.105
ECG Changes	7 (10%)	12 (17.1%)	0.007
First TpTe interval	75.5 (IQR: 22.1)	64 (IQR: 22)	0.339
TpTe interval at the 6th hour	80.5 (IQR: 20.5)	65 (IQR: 22)	0.325
TpTe interval at the 12th hour	71 (IQR: 25)	64 (IQR: 20)	0.870
TpTe interval at the 24th hour	71 (IQR: 25)	64 (IQR: 20)	0.870
First QT interval	389 (41)	370 (42)	0.428
QT interval at the 6th hour	382 (28)	380 (37)	0.701
QT interval at the 12th hour	380 (31.8)	380 (42)	0.561
QT interval at the 24th hour	386 (10.5)	380 (40)	0.884
First TpTe/QT	0.185 (0.05)	0.170 (0.07)	0.501
TpTe/QT at the 6th hour	0.206 (0.04)	0.175 (0.05)	0.091
TpTe/QT at the 12th hour	0.191 (0.06)	0.180 (0.06)	0.980
TpTe/QT at the 24th hour	0.182 (0.07)	0.172 (0.05)	0.905

Mann–Whitney U test and chi-square test, Interval: milliseconds

when the ECG changes in the two groups were compared, it was seen that ECG changes were identified in 10% of the patients with elevated troponin levels and in 17.1% of the patients without elevated troponin levels. The difference was statistically significant (p=0.007). In addition, no differences in TpTe, QT intervals, and TpTe/QT ratios were identified among patients in the group with elevated troponin levels and those in the group without elevated troponin levels (Table 4).

Discussion

It is expressed that the degree of myocardial injury increases as the voltage gets higher (12). Asystole and VF are fatal cardiac problems caused by EI, and besides these, ECG changes, such as sinus tachycardia, non-specific ST-T changes, heart blocks, QT elongation, supraventricular-ventricular arrhythmias, and atrial fibrillation, may also develop (13). Akkaş et al. (14) identified normal sinus rhythm in 76%, sinus tachycardia in 9%, sinus bradycardia in 3%, ST-T changes in 4%, and premature ventricular beats in 1% of the 120 patients with EIs in their study, while cardiac enzymes were elevated in only 4% of the patients and acute coronary syndrome did not develop in any of the patients. In addition, eight patients in their study died due to cardiac problems that started at the time of EI and one died of sepsis. In the patients that survived, no ECG changes that required medical or electrical treatment were observed. Arrowsmith et al. (15) stated that ECG changes were present in 3% of the patients in their study. In the study conducted by Karadaş et al. (16), ECG abnormalities were identified in 29.3% of the patients. In our study, similar to medical literature, the results of the evaluations of the 24-hour ECG monitoring showed that ECG changes were present in 19 (27.1%) of the patients at various time points. The most common ECG change was identified as sinus tachycardia. One of our patients died due to VF and one died due to VT within 6 hours. In addition, cardiac enzymes were high in 11 (15.7%) of our patients.

Some authors recommend ECG monitoring after every EI (3, 12) because ECG changes have been identified in past studies, whereas others state that this is necessary only in selected cases (17). Teodoreanu et al. (18) stated that cardiac monitoring is indicated if cardiac arrest or loss of consciousness occurs, if the ECG is abnormal or if a dysrhythmia is present, if the patient has a history of cardiac disease or important cardiac risk factors before hospital admittance, and if the patient has severe injuries, chest pain, or hypoxia. In the present study, we also investigated the need for 24-hour cardiac monitoring. Normal sinus rhythms were observed in 78.6% of patients at baseline, 90% at the 6th hour, and 92% at the 12th and 24th hours. We observed that only two patients died in the first 6 hours because of cardiac arrest caused by VT or VF and that no other patient experienced serious rhythm disorders after 6 hours. We proposed that, when no ECG changes are present at baseline or in the first 6 hours, prolonged cardiac monitoring is unnecessary for these patients.

We aimed to report, for the first time, the measured TpTe interval and TpTe/QT ratio values as a new method for predicting rhythm disorders in EIs. In past studies on the TpTe interval, it has been identified that the prolongation of the TpTe interval is a potential risk factor for the development of re-entry ventricular arrhythmias (19, 20). In addition, it has been observed that prolonged QT intervals increase the mortality risk in congenital or acquired long QT syndromes and in hypertrophic cardiomyopathy patients with troponin I mutations (11, 21). It has also been shown that they are associated with malignant arrhythmias in prolonged TpTe interval long QT syndrome, hypertrophic cardiomyopathy, Brugada syndrome, and AMI (11). Besides these, another important new parameter is the TpTe/QT ratio. In a study on animals such as cows and pigs, the ratio was measured to be between 0.17 and 0.23 (on average, 0.21 in healthy adults), and it has been reported to play an important role in the electrical stability of the myocardium. It is also very useful in counteracting the individual differences in the heart rate and QT interval (22). It has been stated that the TpTe interval and the new transmyocardial repolarization marker the TpTe/QT ratio are superior to the QT interval in predicting arrhythmias (23). In their study including 353 cardiac arrest cases, Panikkath et al. (7) reported that prolonged TpTe (≥85 ms) and high TpTe/QT ratios are strongly associated with cardiac arrest. Lubinski et al. (24) reported that prolonged TpTe intervals and high TpTe/QT ratios are associated with VT in coronary artery disease patients. Because the TpTe interval and TpTe/QT ratio are important in cardiac rhythm disorders, we investigated if EIs cause prolonged TpTe intervals and high TpTe/QT ratios in our study. However, we were unable to identify any prolongation in the TpTe interval or increase in the TpTe/QT ratio in EIs. In addition, we were unable to identify an association of the TpTe interval or the TpTe/QT ratio with ECG changes in patients with EIs.

It is known from the medical literature that ECG changes occur with both high-and low-voltage currents (25). In their study, Karadaş et al. (16) identified ECG changes in only 8.9% of low-voltage EIs. Rai et al. (26) identified ECG changes secondary to shock or arrhythmia in seven of 58 patients with high-voltage EIs. They also reported that fatal arrest developed in two patients exposed to a high-voltage current in the same study. In our study, there was no difference in ECG changes and there were no troponin level increases between high- and low-voltage EIs.

Akkaş et al. (14) reported that troponin levels were elevated in only 4% of their patients. Jensen (3) was also unable to detect a significant elevation in troponin levels.

In our study, troponin levels were elevated in 15.7% of the patients. However, in our patient group with elevated troponin levels, the number of patients with ECG changes identified was fewer than expected. Thus, we must be careful in using elevation in troponin levels for predicting ECG changes in patients with EIs.

Study limitations

The major limitation of this study is the low number of patients, particularly of patients with ECG changes. Conducting this study in a larger patient group that includes patients with more severe arrhythmias might provide an opportunity to gather more definite results.

Conclusion

Using the TpTe interval and TpTe/QT ratio in predicting potential rhythm disorders that develop in EIs may not be an appropriate approach. In addition, there is no association of the TpTe interval or the TpTe/QT ratio with ECG changes or troponin level increase because of EIs. It is unnecessary to continue cardiac monitoring for longer periods of time if no ECG changes are present at baseline or have not developed in the first 6 hours.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Necmettin Erbakan University Faculty of Medicine.

Informed Consent: Written informed consent wasn't obtained from patients who participated in this study because our study is a retrospective study and the data obtained by screening of the patient files.

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