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Evaluation of Tp-e interval and Tp-e/QTc ratio in crush injury patients

Procena Tp-e intervala i odnosa Tp-e/QTc kod pacijenata sa povredom usled nagnječenja

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Abstract

Background/Aim. While the association between systemic findings and arrhythmia in crush syndrome is well established, limited literature addresses the correlation between the peak and the end of the T wave (Tp-e) interval, Tp-e/QT ratio, and Tp-e/corrected QT (QTc) ratio intervals with crush injury. The aim of this study was to evaluate the potential for arrhythmia in crush injury patients by utilizing the Tp-e interval, Tp-e/QT ratio, and Tp-e/QTc ratio. **Methods.** A retrospective study included 42 patients divided into two groups: a group with crush injuries (n = 23) and a control group (n = 19). Demographic data of patients presented with crush injuries were recorded. These details included their age, gender, vital signs, and comorbidities. Tp-e interval, Tp-e/QT ratio, and Tp-e/QTc ratio were also recorded for comparison between the two patient groups. **Results.** Parameters derived from the electrocardiogram demonstrated significant differences in Tp-e and Tp-e/QTc values between the group with crush injuries and control group. Tp-e was notably higher in patients with crush injuries in comparison to the control group (94.27 ± 27.90 vs. 73.36 ± 11.25, p = 0.024). Furthermore, it was found that the Tp-e/QTc ratio was markedly elevated among patients with crush injuries compared to the control group (0.223 ± 0.064 vs. 0.180 ± 0.030, p = 0.010). Receiver operating characteristic curve analysis showed that at a Tp-e cut-off value of 79.50, trauma severity could be predicted with 82.6% sensitivity and 73.7% specificity, indicating the prediction capability of Tp-e in trauma severity (area under the curve: 0.805, p < 0.001). **Conclusion.** In patients presenting to the emergency department with crush injuries, we posit that the Tp-e interval and Tp-e/QTc ratio on electrocardiogram may function as markers for potential arrhythmia progression.

Key words:
arrhythmias, cardiac; crush injuries; electrocardiography; emergency medicine.

Apstrakt

Uvod/Cilj. Dok je povezanost između sistemskih nalaza i aritmije kod sindroma nagnječenja dobro poznata, ograničen broj radova se bavi istraživanjem korelacije između intervala *the peak and the end of the T wave* (Tp-e), odnosa Tp-e/QT i odnosa Tp-e/*corrected* QT (QTc) sa povredom usled nagnječenja. Cilj rada bio je da se proceni potencijal za nastanak aritmija kod pacijenata sa povredom usled nagnječenja korišćenjem intervala Tp-e, odnosa Tp-e/QT i odnosa Tp-e/QTc. **Metode.** Retrospektivnom studijom obuhvaćeno je 42 pacijenta podeljena u dve grupe: grupa sa povredama usled nagnječenja (n = 23) i kontrolna grupa (n = 19). Zabeleženi su demografski podaci pacijenata koji su se javili sa povredama usled nagnječenja. Ovi podaci uključivali su starost, pol, vitalne znake i komorbiditete pacijenata. Takođe su zabeleženi interval Tp-e, odnos Tp-e/QT i odnos Tp-e/QTc u cilju poređenja između dve grupe pacijenata. **Rezultati.** Parametri dobijeni elektrokardiogramom pokazali su značajne razlike u vrednostima Tp-e i Tp-e/QTc između grupe povređenih usled nagnječenja i kontrolne grupe. Tp-e je bio znatno viši kod povređenih usled nagnječenja u poređenju sa kontrolnom grupom (94,27 ± 27,90 vs. 73,36 ± 11,25, p = 0,024). Utvrđeno je da je odnos Tp-e/QTc bio značajno povišen kod povređenih usled nagnječenja u poređenju sa kontrolnom grupom (0,223 ± 0,064 vs. 0,180 ± 0,030, p = 0,010). Analiza krive *receiver operating characteristic* pokazala je da se pri graničnoj vrednosti Tp-e intervala od 79,50 težina povrede može predvideti sa osetljivošću od 82,6% i specifičnošću od 73,7%, što ukazuje na mogućnost predviđanja težine povrede pomoću Tp-e intervala (površina ispod krive: 0,805, p < 0,001). **Zaključak.** Kod pacijenata koji se javljaju na odeljenje hitne pomoći zbog povreda usled nagnječenja, pretpostavljamo da interval Tp-e i odnos Tp-e/QTc na elektrokardiogramu mogu služiti kao markeri za potencijalnu progresiju aritmije.

Ključne reči:
aritmija; povrede, kraš; elektrokardiografija; medicina, urgentna.

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Introduction

Earthquakes have led to extensive morbidity and mortality, especially in countries prone to earthquakes, like Turkey. Recently, on February 6, 2023, a severe earthquake with its epicenter in Kahramanmaraş caused widespread problems focused in a specific geographic area [1]. Individuals injured during this earthquake, particularly those trapped under collapsed buildings, have manifested systemic symptoms attributed to crush injuries, leading to direct injury to the muscles and ischemic perfusion injury [2]. Systemic manifestations are common in cases of crush syndrome, which often result in acute renal failure, hemorrhage, sepsis, shock, electrolyte derangement, alongside psychological distress and cardiac arrhythmias [3, 4].

A clinical study has shown that measuring QT prolongation and corrected QT interval on an electrocardiogram (ECG) is an effective method for detecting cardiac arrhythmias in patients [5]. The peak and the end of the T wave (Tp-e) interval are utilized in predicting various cardiovascular diseases such as long QT syndrome, acute myocardial infarction, and hypertrophic cardiomyopathy. It measures the duration between the peak of the T wave and the end of the T wave at the isoelectric line, indicating transmural repolarization [6, 7].

Although the development of arrhythmia after crush injury is a well-established relationship, there is limited literature on the potential correlation between the Tp-e interval, Tp-e/QT ratio, and Tp-e/corrected QT (QTc) ratio intervals and crush injury.

The aim of this study was to examine the potential risk of arrhythmia in crush injury patients using the Tp-e interval, Tp-e/QT ratio, and Tp-e/QTc ratio.

Methods

This research is a retrospective study conducted at the Health Science University, Antalya Training and Research Hospital, Department of Emergency Medicine, Antalya, Turkey, examining patients who sought medical help for crush syndrome after an earthquake that occurred in Kahramanmaraş, Turkey, on February 6, 2023.

The study was approved by the Ethics Committee of the Health Science University, Antalya Training and Research Hospital, Antalya (No. 11/22, from August 24, 2023).

Our set of exclusion criteria comprised patients aged below 18 years, individuals with arrhythmias, coronary heart disease, chronic liver and kidney ailments, patients with/possibly having kidney-related pathology from the hospital document system, and previous hospital admissions, as well as pregnant patients and those consuming antiarrhythmic medications such as beta-blockers, calcium channel blockers, digoxin, etc. The study's participants were patients aged 18 years and older who had been diagnosed with crush injury. By this, we mean patients in whom elevated levels of destruction products were found in the blood following muscle destruction. Patients were transported approximately 400–500 km by ship or ambulance. Crush injuries can range in severity from mild to life-threatening. The severity depends on factors like the force of impact, duration of compression, location of the injury, and the extent of tissue damage. Due to the distance of the hospital location from the earthquake zone, only patients with moderate and serious injuries were referred to our hospital, and they were followed up on.

This study included 42 patients divided into two groups: a group with crush injuries (23 patients) and a control group (19 patients). Demographic data regarding patients suffering from crush injuries, encompassing age, gender, vital signs, and accompanying medical conditions, has been compiled. The control group (without any illness) comprised individuals who were admitted to the emergency department due to trauma or non-cardiac pathologies, with comparable age and demographic characteristics established. The control group consisted of patients from regions minimally affected by the earthquake, whose emergency laboratory parameters and ECG findings were unchanged, and who were admitted and discharged from the emergency department with conditions such as vertigo, migraine, or renal colic. Hemogram and biochemical parameters of both patient groups were extracted from their medical files, along with their respective outcomes and trauma-related conditions. The biochemistry parameters of the patients included creatinine [normal range (NR): 0.66–1.09 mg/dL], creatine kinase (NR: 0–172 U/L), calcium (NR: 8.8–10.6 mg/dL), and potassium (NR: 3.50–5.1 mg/dL). ECGs taken upon patients' arrival at the emergency department were recorded at a speed of 50 mm/s and measured for necessary parameters by two senior emergency physicians, whose average was then calculated.

The QT interval was measured and recorded as the time between the onset of the Q wave and the end of the T wave as it returns to the isoelectric line. The QT value was further corrected, using the Bazett formula, and recorded [5, 8]. The Tp-e interval was determined by measuring the duration between the T wave peak and the isoelectric line, which signifies the T wave decline onto the isoelectric line. T wave variables were only assessed in lead V5. The same standard value was asked to be compared in all patient and control groups [5, 8, 9–12]. Additionally, the Tp-e/QTc ratio was recorded to facilitate comparison between the patient and control cohorts.

Statistical analysis

The SPSS software version 25.0 (SPSS Inc., Chicago, IL) was utilized for data analysis of crush syndrome patients. Normality of the data for both groups was assessed using the Kolmogorov-Smirnov test. For variables that followed a normal distribution, comparisons between groups were performed using independent two-sample t-tests. In cases where normal distribution was not observed, the Mann-Whitney *U* test was utilized, while categorical data were assessed using the Chi-square test and Fisher's exact test. A *p*-value of < 0.05 was considered statistically significant.

Results

Age and gender were comparable between the two groups, with no significant differences observed. Upon comparison of vital signs between the groups, the control group showed a marked decrease in systolic and diastolic blood pressures and pulse rate ($p < 0.05$). Significant differences were observed between crush injury and control groups based on the Tp-e and Tp-e/QTc parameters obtained by comparing ECG parameters. The Tp-e parameter for crush injury patients was significantly higher than that for the control group (94.27 ± 27.90 vs. 73.36 ± 11.25, $p = 0.024$). Moreover, the Tp-e/QTc ratio was significantly higher in crush injury patients compared to the control group (0.223 ± 0.064 vs. 0.180 ± 0.030, $p = 0.010$) (Table 1 and Figure 1). Out of the patients with crush injuries, 3 (13.0%) were discharged, 18 (78.3%) were admitted to the ward, and 2 (8.7%) were admitted to the intensive care unit. No deaths occurred during the patients' follow-up (Table 2). Furthermore, the analysis of the receiver operating

Table 1

Statistical analysis of the control and crush injury patients

Parameters	Control group (n = 19)	Crush injury group (n = 23)	*p*-value
Age, years	42.42 ± 19.29	44.6 ± 21.7	0.367
Gender			
male, n(%)	11 (59.7)	13 (56.5)	0.586
Vital sign			
SBP, mmHg	137.91 ± 12.94	141.63 ± 30.21	0.004
DBP, mmHg	81.04 ± 10.21	83.84 ± 20.54	0.003
O_2 saturation, %	96.86 ± 2.92	97.42 ± 1.42	0.039
Pulse, bpm	85.13 ± 10.34	91.26 ± 17.35	0.005
Laboratory			
creatinine, mg/dL	1 ± 0.2	0.79 ± 0.19	0.001
creatine kinase, U/L	69 (29)	1,554 (7,661)	< 0.001
calcium, mg/dL	9.17 ± 0.46	8.33 ± 0.80	0.005
potassium, mg/dL	4.11 ± 0.34	3.80 ± 0.52	0.047
Electrocardiography			
QTc	409.78 ± 24.31	420.52 ± 17.88	0.095
V5 Tp-e	73.36 ± 11.25	94.27 ± 27.90	0.024
V5 Tp-e/QTc	0.180 ± 0.030	0.223 ± 0.064	0.010

SBP – systolic blood pressure; DBP – diastolic blood pressure; bpm – beats *per* minute; Tp-e – peak and the end of the T wave; QTc – corrected QT; n – number.

All values are given as mean ± standard deviation, except for the creatine kinase, which is given as median (interquartile range).

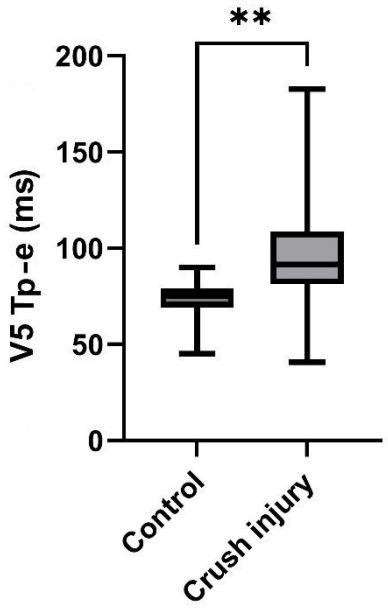

Fig. 1 – Comparison of the Tp-e interval between the crush injury and control groups. Tp-e – peak and the end of the T wave.

***Note*: ** – statistically significant Tp-e interval in crush injury patients compared with control patients ($p = 0.010$).**

Table 2

General demographic data of crush injury patients

Parameters	Crush injury group
Mortality	0 (0)
Length of stay	4 (4)
Hospitalization	
discharged	3 (13.0)
service	18 (78.3)
ICU	2 (8.7)
Diabetes mellitus	2 (8.7)
Hypertension	5 (21.7)
Coronary artery disease	3 (7.1)
Fracture	8 (34.8)

ICU – intensive care unit.
All values are given as numbers (percentages), except for the length of stay parameter, which is given as median (interquartile range).

Table 3

Receiver operating characteristic curves of electrocardiographic parameters between the crush injury and control groups

Variables	AUC	SD	*p*-value	Cut-off	Sensitivity	Specificity
QTc	0.641	0.89	0.114	393.5	95.7	36.8
V5 Tp-e	0.805	0.71	< 0.01	79.50	82.6	73.7
V5 Tp-e/QTc	0.764	0.074	< 0.001	0.219	52.2	100.0

AUC – area under the curve; SD – standard deviation.
For other abbreviations, see Table 1.

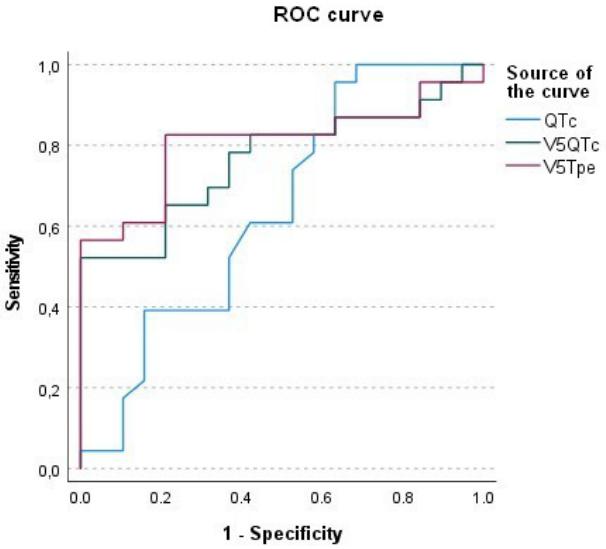

Fig. 2 – Receiver operating characteristic (ROC) curves of electrocardiogram parameters predicted the severity of trauma.
For abbreviations, see Table 1.

characteristic curve indicated that Tp-e accurately predicted the severity of trauma at a cut-off value of 79.50, with a sensitivity of 82.6% and specificity of 73.7% (area under the curve: 0.805, $p < 0.001$) (Table 3 and Figure 2).

Discussion

Chronic fatalities and associated complexities related to heart disease following crush injuries are a well-established phenomenon. A number of cardiovascular conditions emerge as a result of acidosis-induced secondary arrhythmias and electrolyte imbalances [13, 14]. The results of our investigation suggest that Tp-e duration and Tp-e/QTc ratio hold potential as early indicators for detecting arrhythmias after crush injuries.

Numerous studies have emphasized the coexistence of electrolyte imbalances, including hypocalcaemia and hyperphosphataemia, following crush injuries. These have

the potential to cause arrhythmias due to acidosis resulting from the injuries [15]. Additionally, heightened sympathetic activity and overstimulation of cardiac myocytes are recognized factors in trauma patients that may result in arrhythmias [16].

Recently, multiple studies have examined the role of Tp-e interval and Tp-e/QTc ratio as parameters for myocardial repolarization. These studies have revealed associations with cardiovascular and ventricular conditions [17]. Research by Ucar et al. [18] highlighted the potential use of increased Tp-e and Tp-e/QTc values as ventricular repolarization parameters in patients with myocarditis. A recent study conducted by Bilge et al. [19] recommends careful observation of elevated Tp-e and Tp-e/QTc levels on ECG for acute ischemic stroke patients, as they may be at risk of developing arrhythmias. Similarly, Çaltekin and Hidayet [8] found that higher Tp-e and Tp-e/QTc readings may indicate the presence of arrhythmias in blunt chest trauma cases. In a separate study, it was demonstrated that Tp-e interval > 72.5 ms and Tp-e/QT ratio > 0.18 are robust predictors of impaired myocardial reperfusion. The study highlights the ease of applying these parameters [5]. Additionally, ECG changes observed during follow-up appointments of trauma patients were suggested as a useful marker for identifying trauma-associated conditions, such as cardiac contusion [9]. Similarly, a study has demonstrated the usefulness of the Tp-e/QT ratio in predicting significant cardiac incidents after interventional procedures and highlighted its potential role as a marker for coronary ectasia [10]. These parameters have also been found to be valuable as indicators of arrhythmia in medical conditions such as obstructive sleep apnea, ankylosing spondylitis, cardiomyopathy, and hypothyroidism [11, 12].

For the first time in the literature, our study discovered significantly elevated Tp-e and Tp-e/QTc ratios among patients with crush injuries, highlighting the potential utility of these markers as arrhythmogenic indicators. There are several important limitations to this study. First, it is a single-center, retrospective study. Second, the exact duration from the occurrence of the crush injury to the patients' arrival at the emergency department was not precisely determined. Third, ECG monitoring was not conducted after normalization of vital signs, nor during follow-up to assess possible variations in ECG values. Fourth, certain electrolyte and blood gas parameters may have differed between the patient and control groups. Finally, the absence of Holter monitoring limited the ability to fully assess arrhythmia. Therefore, multicenter studies incorporating Holter monitoring and systematic follow-up are needed to address these limitations.

Conclusion

The Tp-e interval and Tp-e/QTc ratio on electrocardiogram could indicate potential arrhythmia in patients with crush injuries who present to the emergency department.

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