Original Article

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Frontal QRS-T Angle in Scorpion Stings

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Abstract

Introduction: The aim of this study was to investigate the change in frontal QRS-T angle in different clinical stages of scorpion stings.

Materials-Methods: In this retrospective study, laboratory data of patients and T angle, QRS duration (ms), QT duration (ms), and QTc duration (ms) of the patients who presented with scorpion sting were calculated and recorded in the data file. The results were analyzed.

Results: Eighty patients who applied to the emergency department with the complaint of scorpion sting were included in our study. Forty-four patients were evaluated as Stage I, 26 as Stage II, and 10 as Stage III. The patient groups did not differ in age ($p = 0.605$) and sex ($p = 0.432$). No significant difference was observed between the laboratory findings of the patients at the time of admission. ECG findings showed a considerable difference in frontal QRS-T angles between scorpion sting stages ($p < 0.001$). Pairwise comparison of the stages with post-hoc analysis revealed a non-significant difference between Stages I and II ($p = 0.143$), and a significant difference between Stages I and III ($p < 0.001$) and Stages II and III ($p = 0.003$). Correlation analysis results showed that the frontal QRS-T angle was negatively correlated with age ($r = -0.281$, $p = 0.016$) and positively correlated with the clinical stage ($r = 0.384$, $p = 0.001$). Multivariate linear regression analysis was performed to identify independent predictors of frontal QRS-T angle, and the stage of the scorpion sting was identified as an independent predictor ($p = 0.001$).

Conclusions: The increase in frontal QRS-T angle in scorpion stings may be used as a parameter that can help both early detections of cardiac involvement and clinical staging.

Keywords: Emergency department, Arthropods, Scorpion sting, frontal QRS-T angle, Electrocardiography.

Introduction

Scorpion stings are more common in subtropical and tropical countries, as climatic conditions, drought, and temperature are important risk factors[1]. Scorpions are venomous arthropods that are members of the class Arachnida and the order Scorpiones. Of the 2700 described species, 30-50 species are poisonous to humans, and most of these species are in the genera *Buthus*, *Parabuthus*, *Mesobuthus*, *Tityus*, *Leiurus*, *Androctonus*, or *Centruroides*, which belong to the Buthidae family. Of these genera, *Androctonus*, *Leiurus*, and *Mesobuthus* are the most medically important scorpion species in Turkey[2]. A scorpion sting can lead to variable and complex clinical manifestations, ranging from a local effect to intense autonomic nervous system responses and a systemic inflammatory reaction. These symptoms often progress to serious cardiac and pulmonary changes that can be fatal, especially in children and the elderly[3,4].

Some electrocardiography (ECG) findings are also observed following scorpion stings. Sinus tachycardia, sinus bradycardia, biphasic and notched T wave, as well as electrical alternans, prolonged QT interval, ST elevation or depression, albeit rare, are ECG abnormalities that can be observed following in scorpion stings[5]. Another parameter obtained in ECG evaluation is the frontal-QRS-T angle. The frontal QRS-T angle is an alternative to the spatial QRS-T angle and can be easily calculated from the anterior QRS axis and T wave axis on a 12-lead electrocardiogram[6]. Reportedly, abnormal spatial and frontal QRS-T angle was associated with both mortality and coronary heart disease[7]. Furthermore, studies have reported that frontal QRS-T angle is associated with non-arrhythmic or sudden cardiac death and risk of cardiovascular disease in the general population[8]. Although, to the best of our knowledge, no study in the literature has investigated QRS-T angle in scorpion stings, QRS-T angle reportedly increases in cases of hypertension, conversive attack, chronic obstructive pulmonary disease, and nonfunctional adrenal adenomas[9-12].

The aim of the present study was to investigate the changes in frontal QRS-T angle and other ECG parameters according to clinical stages of patients who presented to the emergency department with the complaint of scorpion sting.

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Materials and Methods

Patient selection

This retrospective preliminary study was initiated after approval was obtained from the university ethics committee (HRÜ/22.17.23).

Patient records were scanned in the hospital electronic record system with the ICD-10 codes X22 (contact with scorpions) and T63.2 (toxicity of scorpion venom). A patient data file containing basic characteristics such as age and sex, laboratory results, and ECG parameters was created. Patients whose files and ECG records could not be accessed, patients with bundlebranch block and ventricular hypertrophy on ECG, patients with atrial fibrillation, coronary artery disease, patients with previous coronary bypass and heart valve surgery history, and those under 18 years of age were excluded from the study. Patients over 18 years of age who did not meet the exclusion criteria were included in the study. The patients included in the study were clinically divided into four stages[13].

Stage I: Mild pain or paresthesia in the bitten area, no systemic findings

Stage II: Very severe pain or paresthesia extending outside the bitten area (one entire extremity), severe pain on touch.

Stage III: Somatic neuromuscular or cranial nerve involvement findings such as jerks in the extremities, involuntary tremor, cranial nerve involvement (blurred vision, eye movement disorder, salivation, tongue fasciculations, dysphagia, and speech disorder, among others),

Stage IV: Presence of both somatic neuromuscular and cranial nerve involvement. In addition, organ failure findings such as myocardial infarction, pulmonary edema, convulsions, shock

ECG measurements

A 12-lead surface ECG was recorded for all patients with a paper speed of 25 mm/s and an amplitude of 10 mm/mV. To minimize calculation errors, all ECGs were transferred to a digital platform and measurements were made under a magnifying glass. PR duration was calculated from the beginning of the P wave to the beginning of the QRS complex. QRS duration was calculated from the onset of QRS. The corrected QT interval (QTc) was calculated according to Bazett's formula: $QTc = QT/\sqrt{RR}$. QRS axis and T axis data were obtained through automated reports of ECG recordings and frontal QRS-T angle was obtained using the formula QRS axis - T axis.

Laboratory Measurements

White blood cell (3.7–10.1 10e3/µL), hemoglobin (12–18 g/dL), hematocrit (35%–53.7%), and platelet (142–424 10e3/µl) counts were determined with the Alinity HQ (Abbott, USA). Serum glucose (70–105 mg/dL), urea (10–50 mg/dL) and creatinine (0.2–1.11 mg/dL) levels were measured by conventional laboratory methods on Atellica Solution (Siemens Healthineers, Germany).

Statistical analysis

The data was statistically analyzed using the Statistical Package for the Social Sciences v.21.0 (IBM Corporation, Armonk, NY, USA) software package. Shapiro–Wilk test was used to test the normality hypothesis for the distribution of the continuous variables. Non-normally distributed data were expressed as Median (IQR: interquartile range), whereas qualitative data were expressed as percentage values. Kruskal–Wallis test was used to compare the five groups. Pairwise comparisons were then performed using Dunn's post-hoc test and the Chi-Square (cross-tab) was used to compare the categorical data. Pearson correlation analysis was performed to investigate the correlation between the data. After correlation analysis, linear regression analysis was performed with the stepwise method. $P < 0.05$ was considered statistically significant in all analyses.

Results

Eighty patients who applied to the emergency department with the complaint of scorpion sting were included in our study. Forty-four of the patients were evaluated as Stage I, 26 as Stage II, and 10 as Stage III. There was no difference in terms of age ($p = 0.605$) and sex ($p = 0.432$) between the patient groups. There was no significant difference between the laboratory findings of the patients at the time of admission (Table 1). Most commonly stung areas were upper extremity (47.9%, n = 35), lower extremity (38.4%, n = 28), torso (11%, n = 8), and head and neck region (2.7%, n = 2). All of the patients were discharged in good health and no patient died.

ECG findings obtained at the time of admission showed no significant difference in QRS and QT durations, and despite the presence of a difference between QTc values ($p = 0.021$), it was found to be between 360–440 ms. A significant difference was observed in frontal QRS-T angles between different scorpion sting stages ($p < 0.001$). Pairwise comparison of the stages with post-hoc analysis revealed a non-significant difference between Stage I and Stage II ($p = 0.143$), and a significant difference between Stage I and Stage III ($p < 0.001$) and Stage II and Stage III ($p = 0.003$) (Figure 1).

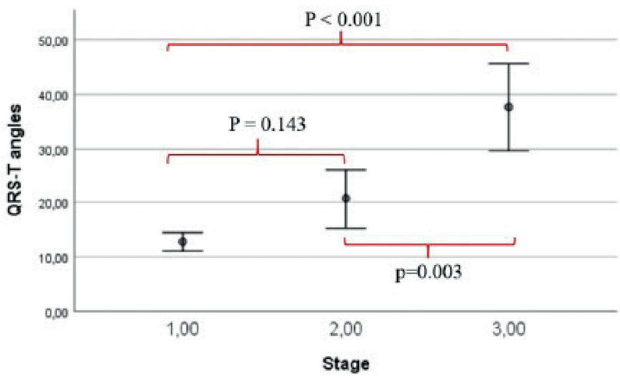

Figure 1:

Table 1: Basic data according to clinical stages of scorpion sting

	STAGE I	STAGE II	STAGE III	P
N (F/M)	44 (24/20)	26 (12/14)	10 (7/3)	0.432
Age (year)	35.50 (27.00–46.00)	33.00 (26.00–40.75)	40.50 (18.00–49.50)	0.605
Systolic blood pressure (mmHg)	120.00 (115.00–144.00)	135.00 (113.75–142.50)	125.00 (90.00–132.50)	0.371
Diastolic blood pressure (mmHg)	78.00 (71.00–87.00)	80.00 (75.25–90.00)	70.00 (56.00–82.50)	0.039
Pulse rate (pulse/minute)	84.00 (73.00–96.00)	80.00 (73.25–88.50)	71.50 (66.00–91.75)	0.385
White blood cell (10e3/µL)	7.56 (6.63–8.20)	7.80 (7.09–8.56)	9.00 (5.88–9.62)	0.422
Hemoglobin (g/dL)	14.00 (12.70–14.60)	13.10 (12.13–14.00)	12.30 (11.90–14.80)	0.032
Glucose (mg/dL)	97.00 (86.00–105.00)	95.00 (84.75–122.50)	108.00 (101.00–115.75)	0.166
Urea (mg/dL)	27.80 (19.20–32.10)	23.00 (14.39–30.43)	25.60 (18.50–30.50)	0.370
Creatinine (mg/dL)	0.70 (0.60–0.80)	0.60 (0.58–0.70)	0.60 (0.57–0.73)	0.304
Potassium	4.00 (3.80–4.30)	4.00 (3.98–4.50)	3.84 (3.70–4.21)	0.361
C-Reactive Protein	0.20 (0.08–0.47)	0.16 (0.05–0.35)	0.25 (0.00–0.91)	0.510
Frontal QRS-T angle	12.00 (8.00–18.00)	16.00 (10.25–37.50) [a]	41.50 (22.00–47.00)[bc]	<0.001
QRS duration (ms)	86.00 (80.00–96.00)	84.00 (78.00–92.50)	90.00 (85.00–95.00)	0.449
QT duration (ms)	398.00 (360.00–434.00)	364.00 (362.00–388.00)	388.00 (368.50–416.00)	0.142
QTc duration (ms)	428.50 (403.00–450.00)	412.00 (399.25–418.25)	415.00 (398.25–422.00)	0.021

a: p = 0.143 when comparing Stage I with Stage II, b: p < 0.001 when comparing Stage I with Stage III, c: p = 0.003 when comparing Stage II with Stage III

Table 2: Correlation analysis results between frontal QRS-T angle and other parameters

	Frontal QRS-T angle	
	r	p
Age (year)	−0.281	0.016
Systolic blood pressure (mmHg)	−0.164	0.165
Diastolic blood pressure (mmHg)	−0.149	0.209
Pulse rate (pulse/minute)	−0.045	0.706
White blood cell (10e3/µL)	0.228	0.053
Hemoglobin (g/dL)	−0.086	0.467
Glucose (mg/dL)	−0.028	0.817
Urea (mg/dL)	0.137	0.248
Creatinine (mg/dL)	0.082	0.491
Potassium	0.199	0.092
C-Reactive Protein	−0.169	0.152
QRS duration	−0.188	0.111
QT interval	0.017	0.886
Corrected QT interval (QTc)	−0.03	0.798
Clinical stage	0.384	0.001

Correlation analysis results showed that frontal QRS-T angle was negatively correlated with age (r = −0.281, p = 0.016) and positively correlated with clinical stage (r = 0.384, p = 0.001). The correlation results between the frontal QRS-T angle and the data are given in Table 2. Multivariate linear regression analysis was performed to identify independent predictors of frontal QRS-T angle, and the stage of scorpion sting was identified as an independent predictor (p = 0.001) (Table 3).

Table 3: Multivariate linear regression analysis showing independent predictors of frontal QRS-T angle

	Unstandardized Coefficients		Standardized Coefficients			
	B	Std. Error	Beta	t	P	95 % Confidence Interval
(Constant)	6.440	2.926		2.201	0.031	0.606–12.274
Clinical stage	6.627	1.890	0.384	3.507	0.001	2.859–10.396
R2 = 0.148, R2 (Adjusted) = 0.136 Model p = 0.001						

Discussion

In the present study, it was found that the frontal QRS-T angle was significantly increased in Stage III scorpion sting patients compared to Stage I and Stage II, but no significant difference was found between Stage I and Stage II patients. In addition, clinical stage of scorpion sting appeared to be an independent predictor of frontal QRS-T angle.

Venom glands and stings of scorpions are located in their curved tails. Most scorpion stings lead to the development of local symptoms, including intense pain in the skin, followed by hyperemia, scarring, and itching after venom inoculation[2]. Hyaluronidases and other enzymes subsequently increased tissue permeability and the toxins reaching circulation spread throughout the body. Circulating toxins accumulate in kidney, blood, liver, lung, heart, and spleen, causing various effects[4,14]. These effects lead to a mixed cholinergic/ adrenergic toxidrome with massive release of epinephrine, norepinephrine and other vasoactive peptides[15]. Lung and heart were affected immediately after injection owing to high blood supply[4]. With the effect of the toxin on the heart and lungs, serious cardiac complications such as myocardial infarction, acute pulmonary edema, cardiogenic shock, myocarditis, and even death can occur[16,17]. QRS-T angle is defined as the angle between the ventricular depolarization and repolarization directions. Therefore, a wide QRS-T angle reflects structural abnormalities that affect depolarization or regional pathophysiological changes in ionic channels that change the repolarization order. In cases when there is an imbalance in the electrical activation and recovery of the ventricles, the QRS axis and T wave axis are no longer aligned and the QRS-T angle widens. Widening of the frontal QRS-T angle was associated with mortality mainly in patients with narrow QRS without bundlebranch block[7] or is a predictor of ventricular arrhythmia[18,19]. Furthermore, the frontal QRS-T angle is reportedly an indicator of arrhythmic events in patients with reduced left ventricular function[18]. However, Aro LA et al. evaluated the ECG recordings of middle-aged patients and found that wide QRS-T angle was associated with arrhythmic mortality; however, QRS-T angle did not predict non-arrhythmic deaths[8].

In scorpion stings, cardiac involvement and ECG changes occur through many mechanisms[5]. Scorpion venom is a water-soluble antigenic complex and acts as a mixture of neurotoxin, cardiotoxin, nephrotoxin, hemolysins, phosphodiesterases, and histamine[20]. Cardiac outcomes such as myocardial damage, pulmonary edema, and cardiogenic shock may occur as a result of the release of vasoactive, inflammatory and thrombogenic peptides and amine components (histamine, serotonin, bradykinin, leukotrienes, and thromboxane) that act on the coronary vasculature and induce coronary artery vasospasm and facilitate platelet aggregation as well as thrombosis16. In addition, scorpion venom inhibits the angiotensin converting enzyme, which leads to the accumulation of bradykinin, which plays a role in the development of pulmonary edema[20]. Another mechanism for the cardiac effects of scorpion stings may be immunoglobulin E-mediated immediate hypersensitivity to scorpion venom in susceptible individuals[21]. In summary, early cardiac dysfunction is associated with the "vascular phase" of scorpion poisoning. This leads to increased left ventricular afterload, impaired left ventricular discharge, increased left ventricular filling pressure and capillary critical pressure, which is characterized by deep catecholamine-related vasoconstriction, resulting in pulmonary edema and increased right ventricular afterload[22]. To the best of our knowledge, there are no studies in the literature that have evaluated frontal QRS-T angles in scorpion stings. As the clinical staging of the scorpion sting increases, the systemic effects of the venom begin to appear. An initial increase in blood pressure and cardiac output, followed by decreased left ventricular function and hypotension may occur. The reason for the increase in frontal QRT-T angle in patients suffering from advanced stages of scorpion stings is not fully known. Although there were no Stage IV patients who developed organ failure in the present study, one of the reasons for the increase in frontal QRS-T angle in Stage III patients may be the intense release of epinephrine, norepinephrine, and other vasoactive peptides that occur after scorpion stings. In addition, changes in blood pressure after scorpion stings may also contribute to the increase in frontal QRT-T angle. In fact, it has been reported that abnormal QRS-T angle is a risk factor for hypertension in Type 2 DM patients[9]. In addition, nondipping hypertension has been associated with an increased frontal QRS-T angle, and it has been suggested that increased blood pressure during sleep may affect cardiac repolarization[23]. QRS-T angle is also used to monitor response to treatment in hypertension. Elffers et al. evaluated the effects of antihypertensive treatment using ECG and found that the QRS-T angle decreased with treatment but was not anatomically associated with a reduction in left ventricular hypertrophy[24]. Although no Stage IV patients were present in the current study, we think that the increase in frontal QRS-T angle due to blood pressure changes seen in the early stages may provide preliminary information about possible cardiac involvement.

Limitations

The main limitation of the present study was that it was conducted in a single-center and the number of patients was relatively small. Although Androctonus and Leiurus are known to be the most medically important scorpion species in our region, the individual scorpion species that the patients in our study were exposed to could not be determined. In addition, the ECG recordings of the patients before the scorpion sting could not be obtained and the baseline frontal QRS-T angles were not known. Another limitation of the study is that it was designed retrospectively, the patients did not have post-treatment ECG recordings, and the change in frontal QRS-T angles with treatment could not be evaluated. These limitations in our preliminary study will guide and provide insights for future studies.

Conclusion

In conclusion, the increase in frontal QRS-T angle in scorpion stings may be used as a parameter that can help both early detection of cardiac involvement and clinical staging.

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