The correlation between electrocardiographic parameters and mortality in non-cardiac ICU patients

K. ERDEM[1], I. DUMAN[2], R. ERGÜN[3,4], D. ERGÜN[3]

[1]Department of Cardiology, Faculty of Medicine, Selçuk University, Konya, Turkey
[2]Department of Medical Pharmacology, Meram Faculty of Medicine, Necmettin Erbakan University, Konya, Turkey,
[3]Department of Chest Diseases, Faculty of Medicine, Selçuk University, Konya, Turkey
[4]Department of Intensive Care, Faculty of Medicine, Selçuk University, Konya, Turkey

Abstract. – OBJECTIVE: This study aimed to determine the correlation between selected electrocardiogram (ECG) parameters (recorded at admission) and mortality in non-cardiac, non-COVID-19 intensive care unit (ICU) patients, and to determine the sensitivity and specificity of a novel admission ECG score (AD-ECG) for predicting mortality. Additionally, the sensitivity and specificity of the AD-ECG and Acute Physiology and Chronic Health Evaluation II (APACHE II) scores for predicting ICU mortality were compared.

PATIENTS AND METHODS: Clinical and laboratory data, and ECG parameters were compared between ICU survivors and non-survivors. ECG parameters (the QTc and Tpe intervals, and the Tpe/QT and Tpe/QTc ratios) and pulse pressure at ICU admission (baseline) were used to calculate the AD-ECG score. Cut-off values for ECG parameters, pulse pressure, and AD-ECG and APACHE II scores were calculated. The sensitivity and specificity of the APACHE II and AD-ECG scores were determined.

RESULTS: The study included 167 patients. Mortality was higher in the patients with comorbidities, mechanical ventilation, and length of ICU stay ($p < 0.05$). The QTc and Tpe intervals, and the TPe/QT and TPe/QTc ratios differed significantly between the survivors and non-survivors ($p < 0.05$). The sensitivity and specificity of the AD-ECG score were similar to those of the APACHE II score. When pulse pressure, and the QTc and Tpe intervals were added to APACHE II, the sensitivity of the APACHE II score increased from 78.9% to 85.5%, and its specificity increased from 75% to 86.8%.

CONCLUSIONS: A novel admission ECG score (AD-ECG) based on ECG parameters (the QTc and Tpe intervals, and the Tpe/QT and Tpe/QTc ratios) and pulse pressure has similar sensitivity and specificity as the APACHE II score for predicting non-cardiac ICU mortality. Adding pulse pressure, and the QTc and Tpe intervals increases the sensitivity and specificity of the APACHE II score; however, as the present study included non-cardiac patients only, additional larger-scale studies are needed to obtain more precise results.

Key Words:
APACHE II, Electrocardiography, Intensive care, Mortality.

Introduction

Accurate prognosis estimation in patients receiving treatment in ICUs is essential for clinical management, improving quality of care, assessing readmission probability, and identifying those eligible for hospital and palliative care services[1]. Mortality is the most widely used objective ICU outcome measure[2]. Patient-centered scoring systems, such as the Simplified Acute Physiology Score (SAPS) and APACHE score, which are based on physiological parameters, are used to predict mortality in critically ill patients[3,4]. The APACHE scoring system was introduced in 1981 for predicting prognosis in ICU patients[5]. Modifications in some parameters led to the subsequent introduction of APACHE II, III, and IV, and APACHE II is among the most widely used systems[6].

On the other hand, the 12-lead ECG remains the most commonly used cardiac diagnostic tool and has been shown to help predict cardiovascular mortality[7]. Although cardiac events are a leading cause of mortality in the ICU, mortality prediction scoring systems do not include the ECG among their parameters. Interpreting the 12-lead ECG is

Corresponding Author: Kenan Erdem, MD; e-mail: erdem.kenebr@yahoo.com

complicated for non-cardiologists; therefore, simplified ECG scores have been recommended to assess cardiovascular event-associated mortality[7]; however, studies on the prognosis of non-cardiac patients in the ICU using ECG are limited[8-12].

The relationship between mortality and some ECG parameters has been established[7,13] in patients with cardiac diseases. Myocardial repolarization can be evaluated using the QT interval (QT) and adjusted QT interval (QTc). Tpe is the interval between the peak and end of the T wave and is an index of ECG transmural dispersion[13,14]. The Tpe/QT and Tpe/QTc ratios are used as an electrocardiographic index of ventricular arrhythmogenesis[14,15]. Pulse pressure is a simple clinical measurement that can also be used to assess mortality in patients with cardiovascular diseases. A high pulse pressure is considered a marker of arterial stiffening and increased afterload, and a low pulse pressure is a sign of reduced stroke volume.

In addition to primary heart diseases, new evidence[8-10] shows that COVID-19 can cause significant ECG changes, especially to the QTc and Tpe intervals. Considering the multitude of COVID-19 patients in our ICU since 2019, the present study only included patients admitted to the ICU during the pre-COVID-19 period. The primary aim of the present study was to determine the correlation between the above-mentioned ECG parameters recorded at admission to the ICU and mortality in non-cardiac, non-COVID-19 patients. An additional aim was to determine the sensitivity and specificity of a novel scoring system for predicting ICU mortality using ECG parameters and compare it to those of the APACHE II score.

Patients and Methods

This retrospective observational study included 208 consecutive patients admitted to a mixed surgical and medical ICU at a tertiary university hospital. The study protocol was approved by the Selcuk University Institutional Ethics Committee (2019/176). Clinical and laboratory data during ICU admission were collected between March 2018 and December 2019. Patients that stayed in the ICU for <24 h, patients admitted from the cardiac ICU, patients diagnosed with acute coronary syndrome, patients with electrolyte imbalances, patients using drugs that prolong the QT interval, and patients without a 12-lead ECG upon admission were excluded.

ECG at ICU admission was evaluated by 2 experienced cardiologists blinded to patient clinical information and outcome. The following ECG parameters were assessed: the PR, QRS, QT, QTc, and Tpe intervals; the Tpe/QT and Tpe/QTc ratios; QRS I voltage; QRS II voltage. The 12-lead ECG recordings were made with patients in the supine position, using an ECG device (Nihon Kohden, Tokyo, Japan) at an amplitude of 10 mm mV^{-1} at a rate of 25 mm s^{-1}. Values were milliseconds (ms), and mean values were taken to increase the accuracy of the measurements. Heart rate and rhythm were also recorded, and the Tpe and QT intervals, and QRS duration were measured.

The QT interval was defined as the distance between the beginning of the QRS and the end of the T wave where it crosses the isoelectric line, and the Tpe interval was defined as the distance between the peak and end of the T wave. In patients with U waves, the end of the T wave was accepted as the lowest point between the T and U waves. Tpe interval measurement was made using precordial leads. The QTc interval was calculated using the Bazett formula[16,17]. The Tpe/QT and Tpe/QTc ratios were also calculated. Inter-observer and intra-observer coefficient variation (calculated by dividing the standard deviation of 2 observations by their mean and expressed as a percentage) was <5%. Cardiac rhythm was evaluated as sinus rhythm and atrial fibrillation[18,19].

Systolic and diastolic blood pressure values and pulse rates were the mean of the hourly measurements during the first 24 h in the ICU. Mean arterial pressure was calculated using the following formula: 2 × diastolic pressure + systolic pressure/3[18,19].

Pulse pressure was calculated by subtracting diastolic pressure from systolic pressure. The corrected calcium value was calculated using the following the formula: corrected total calcium (mg dL^{-1}) = measured total calcium (mg dL^{-1}) + 0.8 × (normal albumin – patient albumin [g L^{-1}])[20].

Using the calculated cut-off values of 4 ECG parameters (the QTc and Tpe intervals, and the Tpe/QT and Tpe/QTc ratios) and the pulse pressure, a novel admission ECG score (0-5) (AD-ECG) was calculated for each patient (Table I).

Statistical Analysis

Data were analyzed using SPSS Statistics for Windows v. 21.0 (IBM Corp., Armonk, NY, USA). Data were shown as number, percentage, and mean ± SD. Patient discharge status was

Table I. Admission ECG score (AD-ECG) and cut-off values of ECG parameters.

	Points				
	0	1	Cutoff	AUC	*p*
QTc (ms)	≤ 412.5	> 412.5	412.5	0.636	< 0.001
TPe (ms)	≤ 89	> 89	89	0.858	< 0.001
TPe/QT	≤ 0.25	> 0.25	0.25	0.843	< 0.001
TPe/QTc	≤ 0.21	> 0.21	0.21	0.790	< 0.001
Pulse pressure (mmHg)	> 40.5	≤ 40.5	40.5	0.305	< 0.001

QTc: Adjusted QT interval, TPe: Interval between the peak and end of the T wave.

evaluated as survivor (coded as 0) and non-survivor (coded as 1). Student's *t*-test was used to compare the APACHE II score, clinical and laboratory data, and ECG parameters between the survivors and non-survivors.

The Chi-square test was used to compare categorical parameters between survivors and non-survivors, including the APACHE II and AD-ECG scores. The sensitivity and specificity of the APACHE II and AD-ECG scores were determined using the logistic regression model. Receiver operating curve (ROC) analysis was performed to determine the cut-off values for each ECG parameter, pulse pressure, and AD-ECG and APACHE II scores. The value with the highest sum of the sensitive and specific values was used as the optimum cut-off value.

A logistic regression model was created by adding pulse pressure, and the QTc and Tpe intervals, which were also used to calculate the AD-ECG to the APACHE II scores; the Tpe/QT and Tpe/QTc ratios were excluded from this regression model because there were strong correlations between the Tpe/QT and Tpe/QTc ratios, and the TPe interval (r > 0.800). Pearson's correlation analysis was performed to determine the relationship between numerical variables. The correlation coefficient (r) was considered weak (0.000-0.249), moderate (0.250-0.499), strong (0.500-0.749), or very strong (0.750-1.000). The level of statistical significance was set at $p < 0.05$.

Results

In total, 208 patients were eligible for the study, but 41 were excluded, as detailed in Figure 1. Of the 167 patients, 88 (52.7%) were

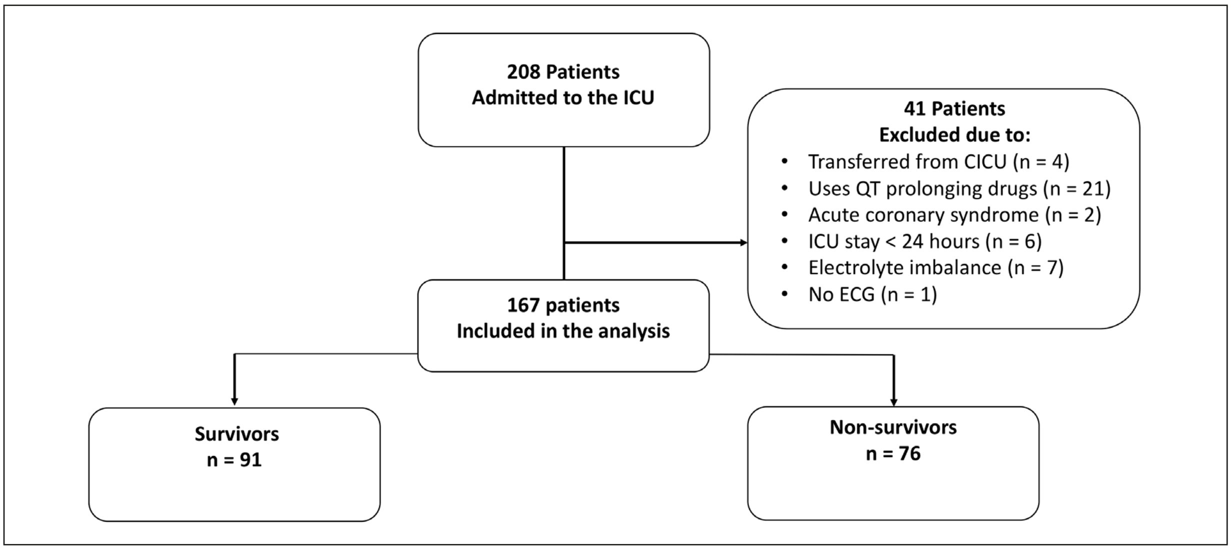

Figure 1. Flowchart of the study population. ICU: intensive care unit, CICU: cardiac intensive care unit.

male, and 79 (47.3%) were female. The mean age of the patients was 59.39 ± 12.34 years. There was no significant difference in mortality according to sex ($p > 0.05$). Demographic, clinical and laboratory findings, health scores, and their association with mortality are presented in Table II. Table III shows the patients' clinical features and mortality scores upon admission to the ICU.

In total, 91 (54.5%) of the patients were discharged from the ICU (survivors), and 76 (45.5%) died (non-survivors). Among the patients, 80 (47.9%) received mechanical ventilation while in the ICU, and 37 (22.2%) had recently undergone surgery. Moreover, 68 (40.71%) of the patients had significant comorbidities. There was no significant difference in mortality according to the history of surgery ($p > 0.05$). Mortality rates were significantly higher in the patients with comorbidities, those that required mechanical ventilation, and the length of ICU stay ($p < 0.05$). Table IV shows a comparison of survivors and non-survivors according to ECG parameters; the QTc and Tpe intervals, and the TPe/QT and TPe/QTc ratios differed significantly between the survivors and non-survivors. ROC analysis showed that the cut-off value for the APACHE II score was 18.5, with a sensitivity of 78.9% and specificity of 75% (AUC: 0.861, $p < 0.001$). Likewise, the cut-off value for the AD-ECG score was 3.5, with a sensitivity of 77.6% and

Table II. Comparison of demographic, clinical and laboratory characteristics and health scores of survivor and non-survivor patients.

	Survivor (n = 91)	Non-survivor (n = 76)	t	p
Demographics				
Male sex	50 (54.94%)	38 (50%)	0.406*	0.524
Age (years)	55.8 ± 14.79	63.64 ± 8.16	-2.317	0.022
Clinical data				
Temperature (°C)	36.82 ± 0.45	36.98 ± 0.70	-1.755	0.081
SAP (mmHg)	119.57 ± 23.7	99.53 ± 26.41	5.157	< 0.001
DAP (mmHg)	71.74 ± 16.27	62.80 ± 18.42	3.330	0.001
MAP (mmHg)	87.68 ± 17,35	75.04 ± 20.30	4.338	< 0.001
Pulse pressure (mmHg)	47.82 ± 16.91	36.73 ± 14.47	4.501	< 0.001
Pulse/minute	96.00 ± 22.41	105.09 ± 24.48	-2.503	0.013
Breaths/minute	21.01 ± 5.49	22.11 ± 6.48	-1.195	0.23
Oxygen Saturation (%)	95.72 ± 3.05	92.07 ± 12.46	2.653	0.01
Laboratory data				
Serum Sodium (mmol/L)	136.92 ± .28	137.44 ± 7.80	-0.549	0.583
Serum Potassium (mmol/L)	4.07 ± 0.53	4.34 ± 0.95	-2.260	0.025
Serum Creatinine (mg/dL)	1.21 ± 1.12	1.79 ± 1.31	-3.059	0.003
Serum Calcium (mg/dL)	8.24 ± 077	7.93 ± 1.11	2.126	0.035
Albumin (g/dL)	2.96 ± 0.71	2.54 ± 0.62	4.003	< 0.001
Corrected calcium (mg/dL)	9.07 ± 0.60	9.09 ± 0.99	-0.185	0.854
Hemoglobin (g/dL)	11.43 ± 2.52	10.90 ± 2.40	1.374	0.171
Hematocrit (%)	34.33 ± 7.64	33.65 ± 7.47	0.579	0.563
WBC (×10^3/mm^3)	13,263.07 ± 11,146.24	15,946.84 ± 12,021.44	-1.495	0.137
MCV (fL)	84.97 ± 6.63	88.24 ± 6.51	-3.190	0.002
Neutrophils (×10^3/mm^3)	58.81 ± 33.85	72.75 ± 30.91	-2.756	0.007
Platelets (×10^3/mm^3)	221.20 ± 104.73	224.86 ± 129.1	-0.202	0.840
RDW	21.20 ± 14.99	19.59 ± 8.98	0.469	0.640
PDW	17.14 ± 0.72	17.38 ± 1.19	-1.612	0.109
Lymphocytes (10^3/mm^3)	8.90 ± 4.60	13.06 ± 7.45	-1.640	0.103
Arterial pH	7.39 ± 0.08	7.43 ± 0.12	-0.315	0.753
Platelets/Lymphocytes	62.45 ± 35.52	57.45 ± 24.10	0.483	0.630
Health scores				
APACHE II score	15.28 ± 6.25	2.5 ± 7.38	-9.053	< 0.001
Glasgow Coma Score	12.56 ± 3.85	8.35 ± 4.62	5.976	< 0.001

*χ^2 value. SAP: Systolic artery pressure, DAP: Diastolic artery pressure, MAP: Mean artery pressure, WBC: White blood count, MCV: Mean corpuscular volume, RDW: Red blood cell distribution width, PDW: Platelet distribution width, APACHE: Acute Physiologic Assessment and Chronic Health Evaluation

Table III. Comparison of patient characteristics, cut-off values of variables and health scores of survivor and non-survivor patients.

	Survivor (n = 91)	Non-survivor (n = 76)	χ^2	p
Patient characteristics				
Days in ICU	5.89 ± 5.33	8.76 ± 7.32	-2.928*	0.004
Chronic Organ Failure	22 (24.17%)	46 (60.52%)	6.043	0.014
Mechanical ventilation	22 (24.17%)	58 (76.31%)	46.582	< 0.001
Recent surgery	24 (26.37%)	13 (17.1%)	1.251	0.263
Cut-off values of variables				
Pulse pressure ≤ 40.5 (mmHg)	38 (41.75%)	54 (71.05%)	14.365	< 0.001
TPe > 89 (ms)	31 (34.06%)	68 (89.47)	52.671	< 0.001
Cut-off values of health scores				
APACHE II score > 18.5	19 (20.87%)	59 (77.63%)	53.269	< 0.001
AD-ECG score (Mean ± SD)	1.99 ± 1.44	3.98 ± 0.9	66.763	< 0.001

**t*-value. AD-ECG: Admission ECG, APACHE: Acute Physiologic Assessment and Chronic Health Evaluation.

specificity of 76.9% (AUC: 0.856, $p < 0.001$), which were similar to those of the APACHE II score (Table V) (Figure 2). The calculated cut-off value, and sensitivity and specificity, respectively, for some ECG parameters were as follows: the Tpe interval – 89 ms, 89.5%, and 65.9% (AUC: 0.858, $p < 0.001$); the Tpe/QT ratio: 0.25, 80.3%, and 79.1% (AUC: 0.843, $p < 0.001$); the Tpe/QTc ratio: 0.21, 80.3%, and 67.0% (AUC: 0.790, $p < 0.001$); the QTc ratio: 412.5 ms, 64.5%, and 51.6% (AUC: 0.636, $p = 0.003$). The regression model that included the APACHE II score, pulse pressure, and the QTc and Tpe intervals increased the sensitivity of the APACHE II score from 78.9% to 85.5% and increased its specificity from 75% to 86.8% (Table III) (Figure 1).

Discussion

The present findings show that prolongation of the QTc interval, an increase in the Tpe interval, and the Tpe/QT and Tpe/QTc ratios, and a decrease in pulse pressure were associated with an increase in ICU mortality in a cohort of

Table IV. Comparison of ECG parameters between survivor and non-survivors.

	Survivor n = 91	Non-survivor n = 76	t	p
PR (ms)	144.86 ± 22.57	144.16 ± 28.35	0.152	0.880
QRS (ms)	95.56 ± 17.96	99.23 ± 30.38	-0.969	0.334
QT (ms)	356.70 ± 46.10	352.48 ± 3.90	0.601	0.548
QTc (ms)	410.69 ± 32.54	430.51 ± 44.24	-3.330	0.001
TPe (ms)	84.29 ± 11.42	102.76 ± 12.2	-9.996	< 0.001
TPe/QT	0.23 ± 0.03	0.29 ± 0.04	-8.688	< 0.001
TPe/QTc	0.20 ± 0.02	0.24 ± 0.03	-7.187 1	< 0.001
QRS I + QRS II (mV)	0.56 ± 0.34	0.56 ± 0.37	-0.007	0.994

QTc: Adjusted QT interval, TPe: Interval between the peak and end of the T wave.

Table V. Specificity and sensitivity of APACHE II and AD-ECG scores.

	B	Wald	p	OR	95% Confidence Interval
APACHE II	0.205	20.239	< 0.001	1.227	1.123-1.342
AD-ECG	1.147	26.236	< 0.001	3.149	2.030-4.885

Cox & Snell R Square: 0.522, Nagelkerke R Square: 0.697, -2 Log likelihood: 93.575, Spesifity: 81.6, Sensitivity: 87.0. AD-ECG: Admission ECG, APACHE: Acute Physiologic Assessment and Chronic Health Evaluation.

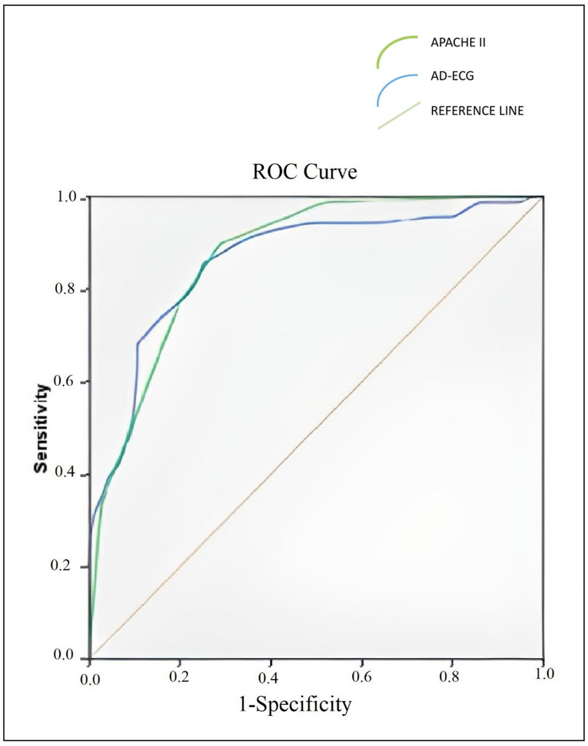

Figure 2. Receiver operating characteristic curve (ROC) for the sensitivity and specificity of APACHE II and AD-ECG scores. APACHE: Acute Physiologic Assessment and Chronic Health Evaluation, AD-ECG: Admission ECG.

non-cardiac ICU patients. The novel mortality score described herein (AD-ECG), based on these 4 ECG variables, has similar sensitivity and specificity as the APACHE II score for predicting mortality. The findings also indicate that adding pulse pressure, and the QTc and Tpe intervals to APACHE II might increase the sensitivity and specificity of the score in non-cardiac ICU patients.

A wide variety of patients (in terms of age and primary disease) are admitted to general adult ICUs. For appropriate supportive and specific treatment to be optimally performed, it is necessary to determine the clinical and laboratory findings and the possible expectation of death during hospitalization. ECG is a simple, low-risk method that can be used in multiple clinical settings. Resting ECG abnormalities are associated with an increased risk of cardiovascular disease[13]. The QTc interval is an important ECG variable; QTc prolongation > 430-450 (ms) is considered a marker of abnormal ventricular electrical activity[19]. In patients without a history of cardiac function defect, QT and QTc interval prolongation are associated with an increased risk of ventricular arrhythmia and are considered independent risk factors for sudden death[20,21]. Tpe interval prolongation and the Tpe/QT ratio are independent and significant predictors of fatal and non-fatal ventricular arrhythmias[21,22]. The most common cause of QTc interval prolongation in the ICU setting is drugs. Antiarrhythmic agents (class IA, III, and IV), antibiotics, and, in particular, macrolides and fluoroquinolones, antiprotozoal and antifungal agents, psychiatric medications, including typical and atypical antipsychotics (especially phenothiazine antipsychotics and butyrophenones), tricyclic antidepressants, SSRIs and SNRIs, antihistamines, promotility and antiemetic medications, and miscellaneous agents can prolong the QTc interval[23-25]. These drugs affect the QTc interval by acting directly on myocyte ion channels or by affecting hepatic metabolism[26]; however, in the present study, patients that had used any of these drugs in the past were excluded, and ECGs were obtained before any of these drugs were administered in the ICU. In fact, critically ill patients can develop a prolonged QTc interval while in the ICU[27]. The QTc and Tpe intervals and the Tpe/QT and Tpe/QTc ratios are considered to be associated with repolarization abnormalities and the risk of ventricular arrhythmias[28].

Data in literature from COVID-19 patients show distinct changes in ECG parameters during hospitalization. Thakore et al[29] recently studied COVID-19 patients admitted to a medical unit or ICU and observed significant differences ($p < 0.0006$) in the QTc interval between the patients that survived (448.1 ± 28.5 ms) and died (461.0 ± 35.2 ms). They further reported that the baseline QTc interval is an independent predictor of mortality and that there is an 8.3% increase in mortality for every 10-ms increase in the QTc interval. Similarly, Rosén et al[8] study on ICU-treated COVID-19 patients reported that 30-d mortality was 16% in patients with a normal ECG, *vs.* 50% in patients with ST-T abnormalities (OR: 6.05 [95% CI: 1.82-21.3]) adjusted for Simplified Acute Physiology Score 3. Although it is known that changes in baseline ECG parameters increase the mortality rate, there is no ECG-based mortality estimation scoring system for non-cardiac ICU patients. Even though the present study did not include COVID-19 patients, the QTc interval findings are consistent with Alsagaff et al[30] recent meta-analysis of 7 studies, which included 2,539

COVID-19 patients and showed that a prolonged QTc interval is associated with poor outcome (weighted means difference [WMD]: 6.04 [range: 2.62- 9.45]; $p = 0.001$).

Currently, there are several scoring systems[5,31,32] available for predicting ICU mortality, including the APACHE, Simplified Acute Physiology Score (SAPS), and Sequential Organ Failure Assessment (SOFA) score; however, none of these scoring systems include ECG parameters as variables. Even though the present study's population was small, the AD-ECG score's sensitivity and specificity did not differ significantly from those of the APACHE-II score. Furthermore, to the best of our knowledge the present study is the first to show that the sensitivity and specificity of the APACHE-II score increases when ECG parameters are included in the calculation. Auer et al[13] studied the addition of ECG abnormalities to traditional risk factors for predicting coronary heart disease events in a population-based study, reporting that the addition of ECG abnormalities was associated with improved risk prediction. The ECG parameters and pulse pressure used in the present study have been used earlier for risk assessment in stroke and cardiac patients. Using multivariate logistic regression for survival analysis in 846 ischemic stroke patients, Prosser et al[33] observed that a long QTc interval (OR: 1.93 [1.31, 2.85], $p = 0.001$) is a predictor of early cardiac morbidity and mortality following ischemic stroke. Cekirdekci and Bugan[34] studied 40 patients with arrhythmogenic right ventricular cardiomyopathy and 65 healthy controls, observing a relationship between an increase in the mortality rate, and a prolonged Tpe interval, and increased Tpe/QT and Tpe/QTc ratios. Teng et al[35] population-based study showed that low pulse pressure is an independent predictor of mortality in patients with EF < 40 and EF > 50, and that high pulse pressure is an independent predictor of mortality in patients with EF 40-49. In the present study, as compared to the survivors, the non-survivors had lower Glasgow Coma Scale scores, oxygen saturation, and serum calcium levels, had higher serum creatinine and potassium levels, and were older. It is important to note that all of these variables are used to calculate the APACHE II score. On the other hand, body temperature, respiratory rate, arterial pH, serum sodium level, hematocrit value, and white blood cell count did not differ significantly between the survivors and non-survivors.

Limitations

The present study has several limitations. Under normal circumstances, a wide range of diseases are responsible for ICU admission. In addition to the primary illness, such comorbidities as diabetes mellitus, hypertension, coronary artery disease, asthma, and immune system dysfunction are common. Due to the fact that cardiac patients are referred to the cardiac ICU at our hospital, the study did not include any patients with primary cardiac pathologies, and patients with a history of using drugs that affect ECG were excluded. The present findings are limited to non-cardiac, non-COVID-19 ICU patients not using medications that affect the QT interval. Due to the small study population, sub-group analysis according to the indications for ICU admission was not performed. Automated ECG and artificial intelligence-assisted ECG (AI-ECG) algorithms are now used to predict mortality in ICU patients[36,37]. AI-ECG algorithms can analyze certain myocardial diseases using a standard 12-lead ECG. Jentzer et al[37] evaluated the ability of AI-ECG to predict mortality in cardiac ICU patients and reported that the AI-ECG algorithm was superior to ECG for predicting mortality.

Conclusions

The QTc and Tpe intervals, the Tpe/QT and Tpe/QTc ratios, and pulse pressure can be used to predict an increased risk of ICU mortality in non-cardiac patients. The novel mortality score based on these parameters (AD-ECG) described herein has similar sensitivity and specificity as the APACHE II score for predicting mortality. Likewise, using these ECG parameters increases the sensitivity and specificity of the APACHE II score. Given the safety, low cost, and wide availability of ECG, the clinical use and evaluation of a mortality score based on ECG could be considered in non-cardiac and cardiac patients. Using AI-ECG algorithms to calculate AD-ECG in the near future may render AD-ECG more versatile. Nonetheless, as the present study's patient cohort was limited to non-cardiac, non-COVID-19 ICU patients, additional research that includes all ICU patients is needed to obtain more precise data.

Conflict of Interest
The Authors declare that they have no conflict of interests.

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Ethical Approval

Ethical approval was obtained from the Institutional Review Board of Selcuk University Faculty of Medicine (2019-176).

Informed Consent

Not applicable, due to the retrospective nature of the study.

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Authors' Contribution

Conception and design: K. Erdem, I. Duman, Acquisition of data: R. Ergün, D. Ergün, K.Erdem; Analysis and interpretation of data: I. Duman and K. Erdem; Drafting the article: K. Erdem, I. Duman, R. Ergün; Validation and final approval: All authors.

ORCID ID

K. Erdem: 0000-0001-6002-5873, I. Duman: 0000-0002-0079-6374, R. Ergun: 0000-0002-6702-9188, D. Ergun: 0000-0002-9890-2250.

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