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Prognostic significance of addition of electrocardiographic findings to the MAGGIC heart failure risk score

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ABSTRACT

Background: The Meta-analysis Global Group in Chronic Heart Failure (MAGGIC) is a scoring system that is easy to use in outpatient or inpatient settings and was developed to predict the survival of heart failure (HF) patients after hospitalization.
Aim: This study aims to determine the prognostic significance of MAGGIC risk score combined with electrocardiography (ECG) parameters in decompensated patients with heart failure with reduced left ventricular ejection fraction (HFrEF) who were hospitalized for worsening HF.
Methods: A total of 562 HF patients with New York Heart Association (NYHA) II-IV functional class who were discharged after hospitalization for decompensated HF between 2013 and 2018 in a single center were included. MAGGIC risk scores of all participating patients were calculated according to baseline characteristics gathered using data from the initial hospitalization for HF. In addition, electrocardiographic findings of all patients were examined.
Results: During the follow-up period (4.5 ± 1.2 years) 177 patients died. MAGGIC scores were observed to be higher in non-survivors compared to surviving patients (28.69 ± 7.01 vs. 22.82 ± 6.05, $p < 0.001$). After a multivariate analysis, MAGGIC score (OR:1.090, $p < 0.001$), development of cardio-renal syndrome (OR:2.035, $p < 0.001$), presence of left bundle branch block (LBBB) (OR:1.931, $p < 0.001$), atrial fibrillation (AF) (OR:1.817, $p < 0.001$), and fragmented QRS (fQRS) (OR:1.671, $p = 0.002$) on ECG were found to be independent predictors of mortality. While the MAGGIC score was shown to predict mortality (AUC = 0.739), its predictive power was improved when combined with AF (AUC = 0.752), LBBB (AUC = 0.745), and fQRS (AUC = 0.757) respectively, as well as in the combined final model (MAGGIC score, AF, LBBB, fQRS) (AUC = 0.787).
Conclusions: Our findings showed that addition of electrocardiographic findings to the MAGGIC heart failure risk score has prognostic significance in decompensated patients with HFrEF.

Introduction

Heart failure (HF) is one of the leading health problems all over the world due to its increasing frequency and prevalence [1]. Estimating mortality in HF patients has become extremely important in order to identify patients who require advanced treatment modalities such as heart transplantation, ventricular assist devices and electrical device therapies.

Internationally validated risk prediction models with high accuracy are required to identify HF patients at risk [2]. Multivariable risk score algorithms, such as Seattle Heart Failure Model (SHFM) [3] and the Heart Failure Survival Score [4] have been developed recently to predict prognosis. The Meta-analysis Global Group in Chronic Heart Failure (MAGGIC) is a scoring system that is easy to use in outpatient clinics or at the bedside and was developed to predict the survival of HF patients after hospitalization. The scoring system has identified 13 independent variables that are used routinely to predict mortality at 1 and 3 years [5]. Retrospective data in individuals with HF have also validated the MAGGIC score's ability to predict all-cause death [6,7]. MAGGIC risk score has been validated in different populations like patients undergoing TAVI, females as well as males, patients who have HF with preserved ejection fraction (EF) and various racial groups [8–11]. In studies comparing the MAGGIC score with different risk modalities, MAGGIC was shown to have better predictive ability in terms of mortality. The addition of various prognostic factors such as natriuretic peptides, apelin

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and nutritional status to MAGGIC score have been previously reported to improve its predictive value [12–14]. In these studies, the inclusion of various variables in the model increased its power.

In patients with HF, an ECG is a bedside diagnostic method with quick results that is used as part of the baseline examination. Presence of some specific ECG patterns such as left bundle branch block (LBBB) [15] and fragmented QRS (fQRS) [16] are known to have poor prognostic value in HF patients. Electrical measures such as fQRS, LBBB, and atrial fibrillation (AF), which can predict arrhythmia related morbidity risk in HF patients, may be combined with scoring systems to enhance their prognostic value. To the best of our knowledge, there is no study in the literature investigating the impact of addition of ECG findings with known prognostic utility to the MAGGIC risk score on the score's predictive ability of mortality and morbidity in HF patients.

Our aim in this study was to determine the prognostic significance of MAGGIC risk score combined with ECG parameters in decompensated patients with heart failure with reduced left ventricular EF (HFrEF) who were hospitalized for worsening HF.

Methods

For this retrospective study, 562 patients with New York Heart Association (NYHA II-IV) who were hospitalized and discharged due to decompensated heart failure between 2013 and 2018 were included in the analysis. We enrolled patients with reduced left ventricular EF (LVEF <40%). Acute decompensated HF was defined by the Framingham criteria as rapid-onset HF or a change in signs and symptoms of HF requiring immediate treatment and hospitalization [17]. The clinical diagnosis of HF was made by the cardiologist.

Patients with the following characteristics were excluded: <18 years of age, presence of active malignant diseases, septic shock, multi-organ failure, severe comorbidities with potential to impact prognosis, pregnancy, implanted ventricular-assist devices (VAD), recent onset heart failure due to acute coronary syndromes. Also patients who died during the index hospitalization for worsening HF and those with missing data deeming calculation of MAGGIC score impossible were also excluded. This study was approved by the Institutional Ethical Committee.

All patients' clinical variables, laboratory tests panels, electrocardiography recordings and echocardiography reports were obtained from medical records filed during hospitalization. Data regarding demographics (age, sex, and ethnicity), medical history (history of myocardial infarction, coronary revascularization, diabetes mellitus, systemic hypertension, stroke, lung disease, peripheral artery disease, and smoking), current medical treatment (angiotensin converting enzyme inhibitor (ACEi), angiotensin receptor blocker (ARB), beta-blocker, diuretic, and aldosterone antagonist), functional capacity NYHA functional class, presence of dyspnea, paroxysmal nocturnal dyspnea, and edema were gathered from patient files. Survival data were collected by telephone contact with patients or their family members or during routine control visits in the heart failure outpatient clinic. MAGGIC risk scores of all participating patients were calculated according to baseline characteristics gathered using data from the initial hospitalization for heart failure.

Definitions

Patients with symptoms and/or signs of heart failure and LVEF <40% are defined as reduced EF heart failure [18]. The NYHA functional classification of heart failure is based on the symptom of patients and the amount of exertion that they can manage without provocation of symptoms. Coronary artery disease was said to be present when the patients included in the study had previous history of PCI or CABG or had stenosis of more than 50% in a major branch in invasive coronary angiography [19]. Chronic kidney disease (CKD) was defined as creatinine clearance below 60 ml/min for more than 3 months [20]. Cardiorenal syndrome (CRS) is defined as 0.3 mg/dl increase in creatinine value at 48th hour compared to baseline creatinine value [21]. The patients were accepted to have diabetes mellitus (DM), hypertension, chronic obstructive pulmonary disease, or hyperlipidemia according to the ICD (International Classification of Diseases) codes defined in the hospital system. MAGGIC score was calculated in order to predict the 1-year mortality rate, which includes 13 clinical variables (https://www.mdcalc.com/maggic-risk-calculator-heart-failure). The following variables were included in the MAGGIC score calculations: age, gender, body mass index (BMI), smoking history, DM, NYHA class, LVEF, chronic obstructive pulmonary disease (COPD), HF duration, serum creatinine, beta-blocker and ACE-I or ARB usage [5].

Data regarding transthoracic echocardiography reports were gathered from patient files. Examinations had been performed using a Philips iE33 echocardiography machine and X5 transducer (Philips Healthcare, Andover, MA, USA) with the patient in the left lateral decubitus position. The standard evaluation included M-mode, 2-D, and Doppler studies according to the recommendations of the American Society of Echocardiography [22]. LV ejection fraction was calculated from apical four and two chamber views by manually tracing end-diastolic and end-systolic endocardial borders, using Simpson's method [23].

Electrocardiography

A 12-lead admission ECG recording was obtained from all patient files. All ECGs (filter range 0.5 Hz to 150 Hz, AC filter 60 Hz, 25 mm/s, 10 mm/mV) were analyzed by 2 independent clinicians who were blinded to the study design and clinical data. In case of disagreement, the final diagnosis was achieved by mutual agreement. All standard 12-lead electrocardiogram (ECGs) were recorded on digitized 12-lead ECG recordings using the on-screen digital caliper software Cardio Calipers version 3.3 (Iconico, Inc., New York, NY). Heart rate, QT, QTc, T peak to T end (Tpe) interval measurements were performed with the Cardio Calipers program in leads DII and V5. Left bundle branch block (LBBB) was classified according to Minnesota Code criteria [24]. The QRS axis was calculated as the mean vector angle in the Einthoven plane, considering the amplitudes of the DI and AVF. QRS axis between 90 and 180 degrees was classified as right axis deviation (RAD), and between 0 and minus 90 degrees left axis deviation (LAD). The following criteria for fQRS were assessed: QRS complex with duration <120 ms with additional R wave (R′), notched R wave, notched S wave, or presence of >1R′ in at least two contiguous leads corresponding to a coronary artery region without the characteristics of bundle branch block, in accordance with previously reported data [25]. Corrected QT (QTc) distances were calculated using Bazet's formula. The distance of Tp-e was obtained from the peak of the T-wave (T peak) to the endpoint of the T-wave (T end) [26]. According to the cohen kappa analysis, intraobserver compliance was measured as 0.976, 0.976, and 1.000 for fQRS, LBBB, and AF, respectively. Interobserver compliance was measured as 0.926, 0.926, and 1.000, respectively.

The primary outcome of this study was the occurrence of cardiovascular death. During their follow-up, the patients were divided into two groups: survivors and non-survivors. Models of MAGGIC score alone and/or in combination with ECG were performed.

Statistical analysis

All statistical tests were conducted using the Statistical Package for the Social Sciences 25.0 for Windows (SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was used to analyze normality of the data. Normally distributed variables were expressed as mean ± standard deviation (SD), while non-normally distributed variables were expressed as median with interquartile range (IQR). The categorical variables are presented as percentages. Chi-square test was used to assess differences in categorical variables between groups. Student's *t*-test or Mann Whitney *U* test was used to compare unpaired samples as needed. The

univariate effects of type of MAGGIC score, CRS, CRP, LBBB, AF, fQRS, Axis deviation and fQRS, Axis deviation and LBBB, QTc interval, and Tp-e interval in patients were investigated using the log rank test. The possible factors identified with univariate analysis were further entered into the Cox regression analysis, with backward selection, to determine independent predictors of mortality. The proportional hazards assumption and model fit was assessed by means of residual (Schoenfeld and Martingale) analysis. Cohen's kappa inter-rater agreement values and inter-observer agreement coefficients for the presence of fQRS, LBBB and AF were calculated. Inter-observer agreement coefficients were compared using Chi-square test. Cumulative survival curves were derived according to the Kaplan-Meier method and differences between curves were analyzed on log-rank statistics. Receiver operating characteristic (ROC) curves were obtained, and the optimal values with the greatest total sensitivity and specificity in the prediction of mortality were selected. All the parameters in the ROC curve analysis were included in the binary logistic regression analysis. Combined model was created with the obtained probability value. A combined model, which was created using mortality predictors, were analyzed by ROC curves. Significance was assumed at a 2-sided $p < 0.05$.

Results

The clinical and demographic characteristics of the 562 decompensated heart failure patients included in the study are shown in Table 1. There was no statistical difference between the groups in terms of gender or age when the patients were divided into non-survivor ($n = 177$) and survivor ($n = 385$) groups. 130 of 177 patients in the non-survivor group were male (73.4%), while 261 of 385 patients the survivor group were male (67.8%). While the average age of patients in the non-survivor group was 65.05 ± 10.69, the average age of patients belonging to the survivor group was 64.55 ± 12.42. BMI ($p = 0.004$), and NYHA ($p < 0.001$) values of non-survivor patients were significantly higher compared to the surviving patients. When the groups were compared in terms of chronic diseases, the frequency of DM ($p < 0.001$) and AF ($p < 0.001$) were found to be significantly higher in the non-survivors group. No significant differences were observed between the groups in terms of other chronic diseases and smoking. The mean systolic admission blood pressure (BP) value of the survivors (125.63 ± 23.38) was higher than the non-survivor patients (115.36 ± 18.29) ($p = 0.008$).

When the groups were compared in terms of laboratory tests; the non-survivor patients' urea ($p = 0.001$), creatinine ($p = 0.001$), potassium ($p = 0.001$), glucose ($p = 0.007$), and CRP ($p = 0.007$) values were found to be significantly higher, with sodium levels being significantly lower ($p = 0.001$). When the echocardiographic findings of both groups were compared, the EF value of survivors (34.11% ± 5.10%) was significantly higher compared to non-survivor patients (28.83% ± 6.97%). While the degree of mitral regurgitation (MR) of non-survivor patients was higher ($p = 0.004$), no statistical difference was observed between the groups in terms of left atrial (LA) size (Table 1). When the groups were compared in terms of medications, no statistical difference was observed.

CRS was observed more frequently in non-survivors ($p < 0.001$). The hospitalization duration of non-survivor patients was significantly longer ($p = 0.001$) than the survivors. The mean MAGGIC score of the patients who were non-survivors was significantly higher than the survivor group (28.69 ± 7.01 vs 22.82 ± 6.05, $p < 0.001$).

When the patients were compared in terms of electrocardiographic findings, the mean heart rate at admission in the non-survivor patients was found to be significantly higher ($p < 0.001$). On the other hand, sinus rhythm was more frequent in the survivor group ($p < 0.001$). QTc and TPe values were higher in non-survivors ($p = 0.010$). The frequency of LBBB ($p = 0.001$) and fQRS ($p < 0.001$) were significantly higher in the non-survivor group. Coexistence of axis deviation (left or right) and fQRS and coexistence of axis deviation and LBBB were also significantly more frequent in the non-survivor group ($p = 0.049$ and $p = 0.004$, respectively) (Table 2).

Logistic regression was carried out by univariate and multivariate analyses that predicted occurrence of mortality. MAGGIC score, CRS, CRP, LBBB, AF, FQRS, coexistence of axis deviation and fQRS, coexistence of axis deviation and LBBB, QTc and Tp-e, were evaluated in univariate analysis. The multivariate analysis re-evaluated parameters such as the MAGGIC score, CRS, CRP, LBBB, AF, fQRS, coexistence of axis deviation and fQRS, coexistence of axis deviation and LBBB, QTc, and Tp-e, which were statistically significant in the univariate analysis. MAGGIC score (OR:1.090, $p < 0.001$), CRS (OR:2.035, $p < 0.001$), presence of LBBB (OR:1.931, $p < 0.001$), AF (OR:1.817, $p < 0.001$), and fQRS (OR:

Table 1
Demographic and clinical characteristics of survivors and non-survivors patients.

	Non-survivors ($n = 177$)	Survivors ($n = 385$)	p
Age (years)	65.05 ± 10.69	64.55 ± 12.42	0.644
Male, n(%)	130 (73.4)	261 (67.8)	0.176
BMI (kg/m^2)	28.10 ± 4.59	27.54 ± 4.42	0.004
NYHA class	3.19 ± 0.63	2.71 ± 0.68	<0.001
Hypertension, n(%)	102 (57.6)	225 (58.4)	0.856
Diabetes mellitus, n(%)	92 (52)	140 (36.4)	<0.001
Hyperlipidemia, n(%)	24 (13.6)	40 (10.4)	0.272
Ischaemic heart disease, n(%)	117 (66.1)	227 (59)	0.107
Smoker, n(%)	80 (45.2)	206 (53.5)	0.067
COPD, n(%)	18 (10.2)	53 (13.8)	0.233
CKD, n(%)	24 (13.6)	44 (11.4)	0.472
Stroke, n(%)	8 (4.5)	29 (7.5)	0.181
Atrial fibrillation, n(%)	63 (35.6)	71 (18.4)	<0.001
Systolic blood pressure (mmHg)	115.36 ± 18.29	125.63 ± 23.38	0.008
LV ejection fraction (%)	28.83 ± 6.97	34.11 ± 5.10	<0.001
Left atrial diameter (mm)	45.29 ± 8.96	44.22 ± 7.41	0.138
Mitral regurgitation degree	2 (1–3)	1 (1–2)	0.004
Creatinine (mg/dl)	1.36 (1.06–1.6)	1.1 (0.9–1.32)	<0.001
Haemoglobin (g/dl)	11.95 ± 1.91	12.22 ± 1.93	0,114
Sodium (mmol/l)	135.90 ± 4.33	137.74 ± 4.28	<0.001
Potassium (mmol/l)	4.65 ± 0.71	4.28 ± 0.62	<0.001
Glucose (mg/dl)	151.49 ± 71.78	133.97 ± 70.87	0.007
Albümin (g/dl)	3.51 ± 0.62	3.50 ± 0.62	0.789
CRP (mg/l)	14 (6.7–40.81)	12 (5–28)	0.007
Beta-blocker, n(%)	132 (74.6)	306 (79.5)	0.193
ACE-I/ARB, n(%)	134 (75.7)	298 (77.4)	0.658
Spironolactone, n(%)	61 (34.5)	105 (27.3)	0.083
Digoxin, n(%)	30 (16.9)	79 (20.5)	0.320
Statin, n(%)	101 (57.1)	196 (50.9)	0.175
Cardiorenal syndrome, n(%)	50 (28.2)	24 (6.2)	<0.001
Length of stay (days)	14 (11–24)	13 (9–17)	0.001
MAGGIC score	28.69 ± 7.01	22.82 ± 6.05	<0.001

Abbreviations: BMI, Body mass index; NYHA, New York Heart Association; COPD, chronic obstructive pulmonary disease; CKD, Chronic kidney disease; LV, left ventricular; CRP, C-reactive protein; ACE-I, angiotensin-converting enzyme inhibitor; ARB, angiotensin-receptor blockers; MAGGIC score,

Table 2
Electrocardiographic findings of patients.

	Non-survivors (n = 177)	Survivors (n = 385)	p
Heart rate, (bpm)	97.36 ± 19.20	88.42 ± 12.74	<0.001
Sinus rhythm, n(%)	114 (64.4)	314 (81.6)	<0.001
QTc interval (ms)	460 ± 53.10	447.41 ± 54.23	0.010
Tp-e interval (ms)	91.60 ± 20.49	86.8 ± 16.98	0.010
Left axis, n(%)	63 (35.6)	118 (30.6)	0.244
LBBB, n(%)	51 (28.8)	65 (16.9)	0.001
fQRS, n(%)	86 (48.6)	121 (31.4)	<0.001
Axis deviation and fQRS, n(%)	33 (18.6)	45 (11.6)	0.049
Axis deviation and LBBB, n(%)	28 (15.8)	30 (7.8)	0.004

Abbreviations: QTc, corrected QT; Tp-e, the peak-to-end interval of the T wave; LBBB, left bundle branch block; fQRS, fragmented QRS.
Data are given as mean ± SD.

Table 3
Univariate and multivariate cox regression analysis on the risk factors associated mortality in patients with HF.

Variable	Univariate			Multivariate		
	HR	95%CI	*p*	HR	95%CI	*p*
MAGGIC score	1.110	1.089–1.131	<0.001	1.090	1.066–1.113	<0.001
CRS	3.558	2.560–4.944	<0.001	2.035	1.385–2.990	<0.001
CRP	1.004	1.001–1.007	0.013	1.000	0.996–1.004	0.983
LBBB	1.844	1.331–2.554	<0.001	1.931	1.350–2.763	<0.001
AF	2.445	1.790–3.341	<0.001	1.817	1.318–2.506	<0.001
fQRS	1.707	1.271–2.293	<0.001	1.671	1.200–2.328	0.002
Axis deviation and fQRS	1.502	1.024–2.205	0.038	1.405	0.798–2.472	0.239
Axis deviation and LBBB	2.008	1.340–3.008	0.001	1.362	0.757–2.450	0.303
QTc interval	1.003	1.001–1.006	0.015	0.999	0.995–1.002	0.355
Tp-e interval	1.014	1.006-–1.021	0.001	1.008	0.998–1.017	0.103

Abbreviations: CRS, Cardiorenal syndrome; CRP, C-reactive protein; LBBB, left bundle branch block; AF, atrial fibrillation; fQRS, fragmented QRS; QTc, corrected QT; Tp-e, the peak-to-end interval of the T wave.

1.671, $p = 0.002$) were determined as the independent predictors of mortality (Table 3).

The specificity and sensitivity of the MAGGIC score, AF, LBBB, and fQRS values in predicting patient mortality were evaluated by ROC analysis (Fig. 1). As depicted by the blue line representing the MAGGIC score, the area under the curve (AUC) was measured as 0.739 [0.697–0.781], $p < 0.001$. The MAGGIC score was determined to have a cutoff value of 25.5 with 65% sensitivity and 71% specificity. In addition, as depicted by the red line representng the frequency of AF, the green line the presence of LBBB and the orange line the presence of fQRS respectively, AUC values were measured as 0.586 (0.534–0.638), $p = 0.001$; 0.560 (0.507–0.612), $p = 0.023$ and 0.586 (0.534–0.637), $p = 0.001$ (Fig. 1). Then, the combined predictor effect of the variables included in the ROC analysis with binary logistic regression analysis was evaluated. The result obtained from binary logistic regression analysis was re-evaluated with ROC analysis (Fig. 2): As shown by the blue line representing the value of the combined diagnostic model with the MAGGIC score and the presence of AF, the AUC was found to be 0.752. The combined diagnostic model using MAGGIC score and the presence of LBBB (orange line) showed an AUC value of 0.745 (Fig. 2). AUC was found to be 0.757 for the combined diagnostic model with the MAGGIC score and the presence of fQRS (green line, Fig. 2). Then, through ROC analysis, all the dual combined data (MAGGIC score, AF, LBBB, FQRS) were assessed in a single model. Combined model was represented in red and the measured area under the curve (AUC) was found to be 0.787 (Fig. 3). The AUC values obtained with the ROC

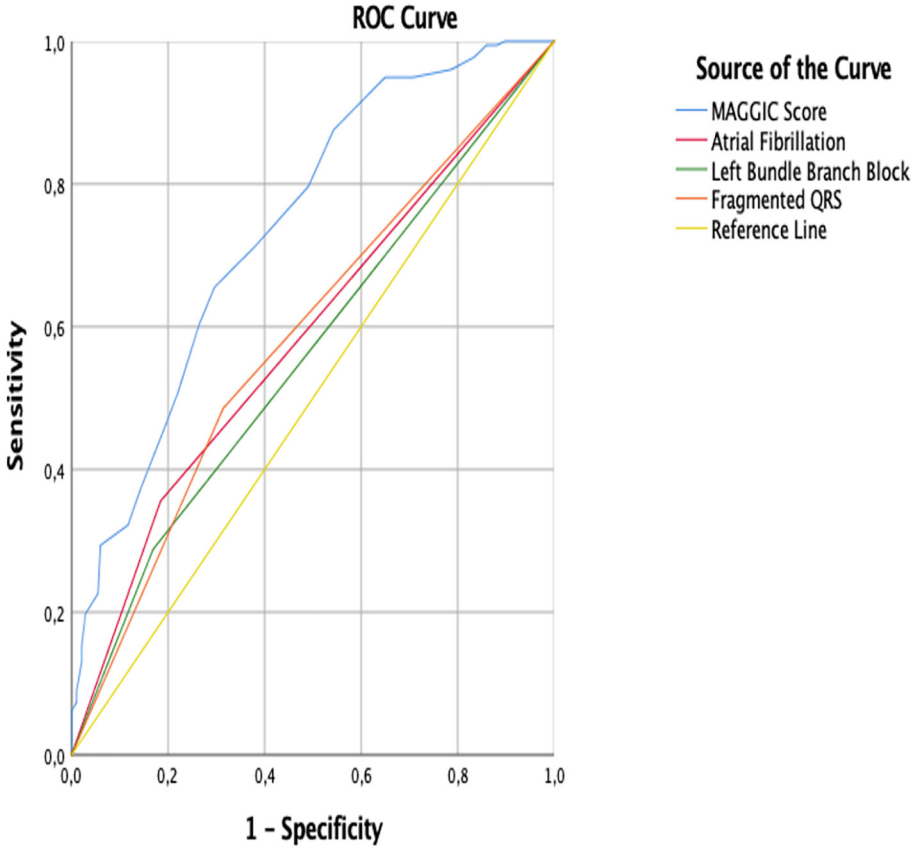

Fig. 1. The ROC curves for MAGGIC scores, AF, LBBB and fQRS.

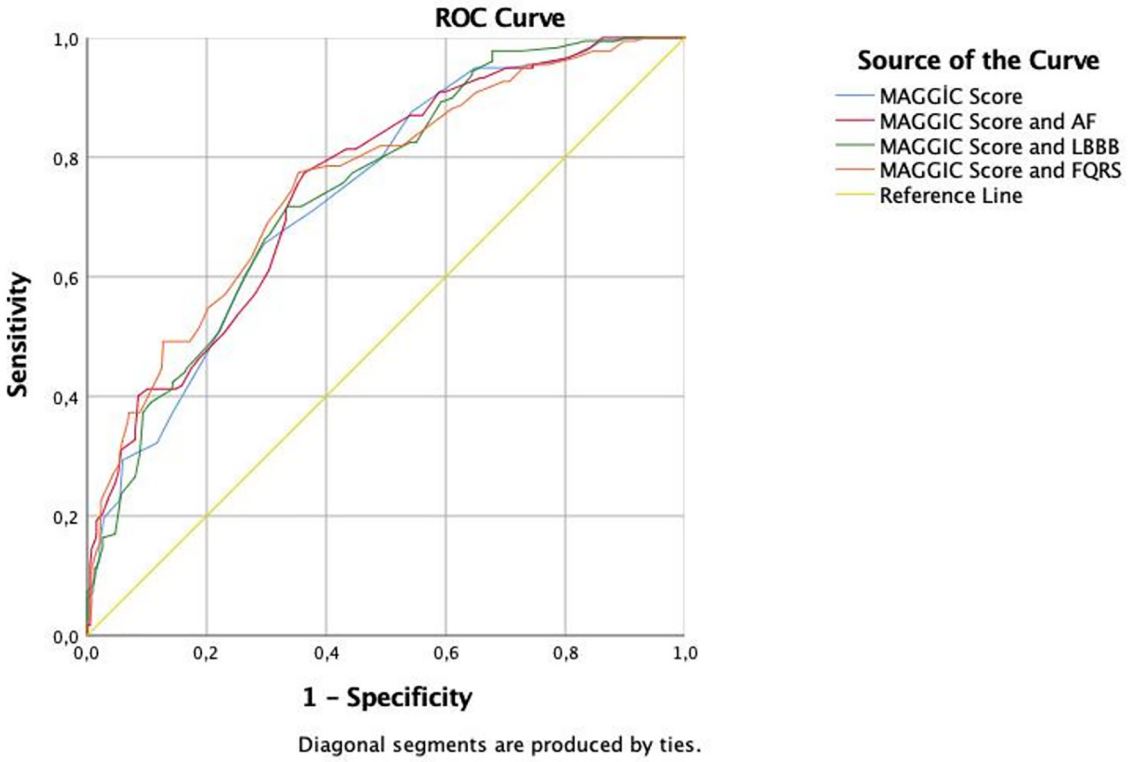

Fig. 2. The ROC curves for MAGGIC-AF scores, MAGGIC-LBBB scores, MAGGIC-fQRS scores.

were compared in the analysis performed with the Delong method. The AUC value obtained from the combination of MAGGIC score, AF, LBBB and fQRS showed a statistically significant difference compared to all combinations given in Figs. 1, 2 and 3 ($p < 0.05$).

Discussion

Our aim in this study was to determine the prognostic significance of MAGGIC risk score combined with ECG parameters in decompensated

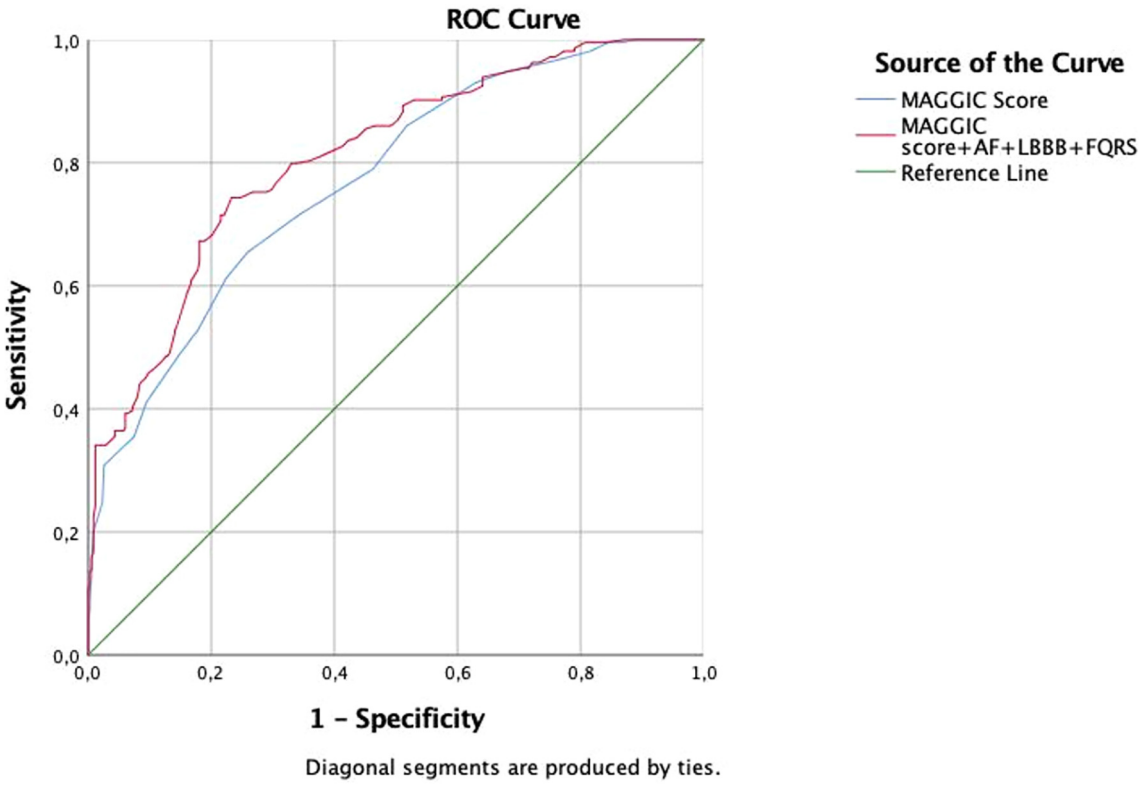

Fig. 3. ROC analysis with a single model created with all of the combined data (MAGGIC score, AF, LBBB, and fQRS).

patients with HF and reduced LVEF. The main findings of our study are: i) MAGGIC scores were observed to be higher in non-survivors compared to survivor patients. ii) After a multivariable analysis, MAGGIC score (OR:1.090, $p < 0.001$), CRS development (OR:2.035, $p < 0.001$), presence of LBBB (OR:1.931, $p < 0.001$), AF (OR:1.817, $p < 0.001$), and fQRS (OR:1.671, $p = 0.002$) on ECG were found to be independent predictors of mortality. iii) The MAGGIC score was shown to predict mortality more strongly when combined with AF, LBBB, and fQRS separately, with the highest predictive ability attained when all three ECG findings are used together with the MAGGIC score.

Heart failure is one of the most important causes of morbidity and mortality worldwide, necessitating development of scoring systems to predict prognosis [3,4]. When compared to other systems, the MAGGIC score has been shown to predict mortality best in HF patients [27]. The MAGGIC risk model is simple to use and includes parameters routinely checked in patients and has been shown to be highly effective in predicting 1- and 3-year mortality in HF patients. In our study, like previous studies, MAGGIC score was shown to be a long-term predictor of mortality in patients with HF.

Since many parameters with proven prognostic importance in predicting mortality in heart failure are not included in the MAGGIC score, studies have been conducted on the prognostic importance of the combination of the MAGGIC score with different parameters. In a study including end-stage HF patients awaiting heart transplantation, it was shown that adding apelin levels to the MAGGIC score had higher sensitivity and specificity in predicting 1-year mortality [12]. The CONUT (Controlling Nutritional Status) score (serum albumin, total cholesterol, lymphocyte count) has been shown to significantly improve the 12-month mortality estimate when combined to the MAGGIC score [14]. In a study performed by Heijden et al., ECG was added to the risk scoring model, found QRS morphology and change in QRS duration due to CRT in the SHFM improves the prognostic value of this model in HF patients with CRT-D [28].

Although the SHFM and MAGGIC risk models provide significant information about mortality rates, they are insufficient to predict which patients will have a clinical outcome, according to a study that included 10,930 patients with HF. In a study that included 6859 HF patients, the MAGGIC score was insufficient identifying sudden cardiac death (SCD), especially in patients with chronic HF who were predicted to have a low risk of death [29], which led to the need to combine this model with parameters which may be related to the occurrence of arrhythmic events.

Many parameters in ECG have been shown in various studies to play a role in predicting prognosis and defining the risk of sudden death in HF patients [30]. Patients with LBBB have increased rates of cardiovascular mortality, sudden cardiac death, and HF [31]. Presence of fQRS on ECG, which is a marker of myocardial fibrosis, has been shown to be an indicator of arrhythmic events in patients with coronary artery disease or dilated cardiomyopathy [32,33]. AF is a common arrhythmia and is associated with impaired quality of life and increased risk of stroke and death [34]. Since patients with HF (especially NYHA II-III) are more likely to die due to arrhythmias [35,36], it is important to include arrhythmic markers in scoring systems in this patient group. In our study, the presence of ECG parameters like presence of AF, LBBB and fQRS showed good prognostic power. The addition of these markers to MAGGIC models has increased their prognostic importance in predicting long-term mortality. The differences between the AUCs obtained by the combination of ECG parameters with the MAGGIC score were significant. This revealed that MAGGIC-ECG was significantly better predictive of long-term mortality in HF patients than the individual components.

Our study has some limitations. First, this is a single-center study involving a relatively small number of patients. Only mortality was taken as the endpoint in the study and re-hospitalization was not included. Markers such as NT-proBNP and troponin, which have high prognostic importance in HF, are not included in the scoring system due to the low percentage of availability in patient records and retrospective nature of the study. Only HFrEF patients were included in the study, and utility in patients with HFpEF is not investigated.

Conclusion

This study may have clinical importance as adding ECG parameters to the MAGGIC score in patients hospitalized and discharged due to decompensated HF enhances its performance in demonstrating long-term mortality. In patients with HFrEF, an effective risk model should be able to predict prognosis and risk stratification, as well as guide the design of future clinical trials. Future HF risk models should include ECG as a covariate to better predict prognosis. To improve the utility of new scoring systems in clinical practice, larger, multicenter, and prospective studies incorporating biomarkers and ECG parameters are needed.

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CRediT authorship contribution statement

Barış Ikitimur: Supervision, Visualization, Writing – original draft, Methodology, Project administration. **Hasan Ali Barman:** Conceptualization, Methodology, Project administration, Resources, Software, Writing – original draft, Supervision. **Omer Dogan:** Data curation, Software, Writing – original draft, Writing – review & editing, Methodology. **Adem Atıcı:** Formal analysis, Writing – review & editing, Writing – original draft. **Bengisu Keskin Meriç:** Data curation, Investigation. **Sait Mesut Dogan:** Data curation, Investigation. **Rasim Enar:** Data curation, Formal analysis, Writing – original draft.

Declaration of Competing Interest

None.

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