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Original Article

Prognostic Value of ECG Findings in Patients With Decompensated Heart Failure

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ABSTRACT

Background: ECGs are recognized as a useful tool for improving the prognosis and management of patients with heart failure (HF). However, the relationship between ECG findings and clinically important outcomes remains unclear in patients with HF. This study aimed to describe ECG findings in patients with HF and their prognosis.

Methods: This cross-sectional study was conducted on a convenience sample of 50 hospitalized patients with decompensated HF at Shafa Hospital, Kerman University of Medical Sciences, over a 1-year period, from 2017 through 2018. All eligible patients who met the inclusion criteria of having a history of HF and being likely to be hospitalized in the cardiology unit were enrolled during the study period. Upon admission and before discharge, ECGs were performed, and the findings (QT interval, QRS duration, and PR interval) were compared. Three months after discharge, a follow-up was done concerning mortality. The Wilcoxon test and the Mann-Whitney *U* test were used to compare the ECG indices of the patients. SPSS, version 23, was utilized for data analysis.

Results: More than half of the patients were diagnosed with severe HF (n=29, 58%). The length of hospital stay and history of admission were higher in patients with severe HF than in those with moderate HF ($P<0.0001$). Heart rate significantly decreased in patients with moderate and severe HF ($P=0.001$ and $P=0.04$, respectively). There was no significant difference between survivors and nonsurvivors regarding ECG changes.

Conclusions: Based on the present findings, widened QRS, prolonged PR interval, and increased heart rate were associated with poor outcomes. QRS duration, PR interval, and heart rate measured upon admission could be used to improve physicians' clinical decisions.
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KEYWORDS: ECG indices, Heart failure, Iran, Clinical outcomes

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The primary etiology of congestive heart failure (CHF) is a structural or functional cardiac abnormality, which results in impaired left ventricular (LV) performance due to multiple underlying clinical conditions. [1,2] Structural cardiac defects, such as LV hypertrophy, and functional aberrations, including LV systolic dysfunction, adversely affect LV contractility and left ventricular ejection fraction (LVEF). [1-5] Consequently, heart failure (HF) may manifest owing to structural and/or functional cardiac disorders, which precipitate venous congestion and ultimately lead to CHF. [6]

It is estimated that five million people are affected by CHF in the United States, predominantly elderly patients above 65 years. [7] Although the magnitude of this problem cannot be precisely assessed, the estimated cost of CHF in the United States was 27.9 billion dollars in 2005 [7] and 33.2 billion dollars in 2007. [8] In the United Kingdom, CHF accounts for almost 2% of the National Health Service (NHS) budget, mostly for hospital admissions. [9] Patients hospitalized for HF are at risk of prolonged hospitalization, in-hospital mortality, and early post-discharge death or readmission. [10] Given the high cost of inpatient HF care and the expansion of at-risk populations, [3] there is an urgent need for strategies to shorten patients' length of stay, prevent readmissions, and provide appropriate care, depending on the stage of disease in the natural history of HF. [10]

ECGs serve as the primary noninvasive diagnostic tool for CHF and are routinely employed by clinicians to identify the characteristic signs of this condition in patients. [11] In addition to their efficacy in diagnosing CHF, ECGs are valuable for the prognostication and management of patients with CHF. [12,13] Changes observed on the 12-lead ECG are generally nonspecific for CHF. However, specific ECG patterns, particularly during severe CHF (with ischemic and nonischemic cardiomyopathy), include intraventricular conduction delays and low-amplitude QRS complexes (comprising the Q wave, the R wave, and the S wave) due to multiple previous myocardial infarctions (MIs) and ventricular aneurysms. [14] Abnormal MI is often accompanied by disturbances in electrical conduction. In HF patients with reduced EF, the prevalence and annual incidence of QRS prolongation are elevated [15-17] and associated with adverse outcomes. [17,18] Studies conducted on the general population have demonstrated that prolongation of the PR interval (the duration from the onset of the P wave to the start of the QRS complex) is associated with an increased risk of atrial fibrillation, pacemaker implantation, and mortality. [19-22]

Conversely, prominent studies, including the Atherosclerosis Risk in Communities (ARIC) [23, 24] and Framingham Heart Study, [20] have recently reignited controversies over the pathological implications of PR prolongation since this ECG finding is consistently associated with an increased risk of atrial fibrillation in the target populations. In the Framingham Heart Study, PR prolongation is additionally linked to an elevated risk of pacemaker implantation and all-cause mortality. [20] Although several descriptive studies have investigated individual ECG indices in populations of chronic HF patients, [25-28] few studies have comprehensively evaluated the ECG findings of patients with acute HF. [10, 29-32]

Studies conducted on chronic HF patients have demonstrated associations between poor long-term outcomes and the presence of widened QRS, [33] left bundle branch block (LBBB), prolonged PR interval, [33] and increased heart rate (HR). [12] Despite their prognostic significance, these ECG indices are not routinely utilized by clinicians and have not been incorporated into clinical risk

stratification tools. [34-39] Consequently, the relationship between ECG findings and clinically important outcomes remains unclear in patients with acute HF. The present study aimed to characterize ECG findings in patients with acute HF and to determine which features are associated with clinical outcomes.

METHODS

Participants and Setting

This cross-sectional study was conducted on patients hospitalized in the emergency department and the CCU of Shafa Hospital, Kerman University of Medical Sciences, between 07/09/2017 and 07/09/2018. The study population was composed of all patients admitted to the hospital with decompensated HF and severe symptoms during the study period. Patients were eligible for inclusion if they had a history of HF and were likely to be hospitalized in the CCU.

A convenience sampling method was employed to recruit participants. All eligible patients who met the inclusion criteria during the study period were enrolled. The sample size of 50 patients was determined based on the feasibility of recruitment and the availability of eligible patients during the study period.

Data Collection

Upon hospitalization, ECGs were conducted for all the patients. During the patient's hospital stay, all the necessary medical and nursing care was provided. All the patients were treated based on conventional methods and the latest scientific resources. After admission to the hospital and the day before discharge, they all underwent another ECG. ECG indices, collected upon admission and before discharge (after treatment), including QT interval (the time from the start of the Q wave to the end of the T wave), QRS duration, and PR interval, were compared. Along with these indices, some secondary indicators, such as age, sex, length of hospital stay, and history of admission, were also investigated. Three months after discharge, a follow-up was conducted concerning mortality.

Ethical Approval

The protocol of the present study was reviewed and approved by the Ethics Committee of Kerman University of Medical Sciences (Ethics No.: IR.KMU.REC.1396.1494).

Statistical Analysis

Data were described by measuring means (± standard deviation [SD]), medians and interquartile ranges (IQRs), and frequencies. The Kolmogorov-Simonov test was performed to evaluate the normal distribution of quantitative data. The Wilcoxon test was also utilized for the pairwise comparison of ECG indices, such as PR, HR, QRS, and QT, upon admission and at discharge. The Mann-Whitney *U* test was used to compare the ECG indices of the patients according to the severity of HF, age, and length of hospital stay. Additionally, the χ^2 and Fisher exact tests were carried out to compare sex, history of admission, and mortality 3 months after treatment. SPSS, version 23, was used for data analysis. A *P* value ≤0.05 was considered significant in 2-tailed tests.

RESULTS

Demographic and Clinical Characteristics of the Patients

In the present study, 31 men (62%) and 19 women (38%) were evaluated. The mean (±SD) age of the patients was 64.96±11.47 years (range =38–85 y). The mean (±SD) LVEF of the patients was 24.50±9.96 (range =10–45) upon admission. The shortest length of hospital stay was 4 days, and the longest stay was 9 days (mean =6.08±1.39

d). Overall, 42 patients (84%) were hospitalized for up to 1 week. Based on the results, 35 patients (70%) had a history of admission. With respect to the severity of HF, more than half of the patients had severe HF (n=29, 58%). The results indicated a significant decrease in both QRS duration and HR at discharge compared with admission in all the patients (*P*=0.04 and *P*=0.0001, respectively) (Table 1).

Severity of HF

The present results showed that the length of hospital stay and history of admission significantly differed between the patients, depending on the severity of HF (Table 2). Patients with severe HF had longer hospital stays than those with moderate HF (*P*≤0.001). All patients with decompensated HF had a history of hospitalization, while only 6 patients (28.6%) had a history of admission (*P*≤0.001) (Table 2).

Changes in ECG Indices Based on HF Severity

The present results showed some significant changes in the ECG indices of patients based on the severity of HF at admission and discharge. Regarding the severity of HF, QRS duration was not significantly different between the patients at admission and discharge (*P*=0.44 and *P*=0.83, respectively). On the other hand, in patients with moderate HF, QRS duration significantly decreased upon discharge compared with the admission time (*P*=0.02). A significant change was also observed in HR upon discharge since patients with moderate HF had a lower HR than those with severe HF (81.95±11.97 vs 90.62±11.99; *P*=0.02). However, in both severe and moderate HF groups, a decreasing trend was observed in HR from the time of admission until discharge (*P*=0.04 and *P*=0.0001, respectively) (Table 3).

Table 1: Comparison of ECG indices in patients at admission and discharge

ECG Indices	Admission Time	Discharge Time	
QRS duration, ms	91.40±23.38	88.80±22.73	0.04*
PR interval , ms	168.40±32.85	165.40±30.58	0.19*
QT interval, ms	431.02±26.55	428.32±23.06	0.36*
Heart rate, bpm	98.26±20.68	86.98±12.62	0.0001*

* Wilcoxon test (*P* value)

Table 2: Comparison of the demographic characteristics, clinical findings, and outcomes of patients with HF based on the severity of disease on admission

Variable	Severe HF (n=29)	Moderate HF (n=21)	*P* value
Age, mean, SD	63.89 (12.21)	66.42 (10.48)	0.44*
Sex, male, %	19 (65.6)	12 (57.1)	0.54**
Length of hospital stay, d, median (range)	7 (5-9)	5 (4-7)	0.0001*
History of admission, %	29 (100)	6 (28.6)	0.0001*
Mortality, %	4 (13.8)	1 (4.8)	0.38*

HF: heart failure

*Mann-Whitney *U* test **χ^2 test

Table 3: Changes in ECG indices according to the severity of HF

Variable	Stage	Severe HF (n=29)	Moderate HF (n=21)	*P* value
QRS duration, ms	Admission	89.65 (24.84)	93.80 (21.55)	0.44*
	Discharge	88.62 (23.86)	89.04 (21.65)	0.83*
P value		0.59**	0.02**	--
PR interval, ms	Admission	175.86 (33.54)	158.09 (29.60)	0.08*
	Discharge	172.06 (31.09)	156.19 (28.01)	0.09*
P value		0.17**	0.56**	--
QT interval, ms	Admission	427.86 (24.92)	435.38 (28.69)	0.32*
	Discharge	427.44 (23.45)	429.52 (23.03)	0.92*
P value		0.88**	0.19**	--
HR, bpm	Admission	97.31 (21.02)	99.57 (20.63)	0.70*
	Discharge	90.62 (11.99)	81.95 (11.97)	0.02*
P value		0.04**	0.001**	--

HF: heart failure; HR: heart rate

*Mann-Whitney *U* test ** Wilcoxon test

Table 4: Changes in ECG indices at admission and discharge according to patient survival

Variable	Stage	Survivors (n=45)	Nonsurvivors (n=5)	*P* value
QRS duration, ms	Admission	90±22.96	104±26.07	0.22*
	Discharge	86.66±21.95	108±22.80	0.06*
P value		0.01**	0.31**	--
PR interval, ms	Admission	169.33±33.46	160±28.28	0.43*
	Discharge	166.44±30.83	156 (29.66)	0.25*
P value		0.24**	0.31**	--
QT interval, ms	Admission	431.84±26.80	423.60±25.73	0.51*
	Discharge	429.62±23.00	416.60±22.51	0.25*
P value		0.54**	0.06**	--
HR, bpm	Admission	97.68±20.86	103.40±20.10	0.43*
	Discharge	86.88±12.35	87.80±16.49	0.96*
P value		0.001**	0.08**	--

HR: heart rate

*Mann-Whitney *U* test ** Wilcoxon test

Changes in ECG Indices Based on Survival

The patients underwent a follow-up for 3 months. During this period, 5 patients expired. The ECG indices based on survival are shown in Table 4. There were no significant differences regarding ECG indices at admission and discharge between survivors and nonsurvivors. Conversely, QRS duration and HR significantly decreased from admission until discharge among the survivors (P=0.01 and $P \leq 0.001$, respectively).

DISCUSSION

In this study, more than half of the patients were diagnosed with severe HF based on EF. The length of hospital stay and history of admission were higher in these patients than in those with moderate HF. The present results showed that among ECG indices, HR significantly decreased after routine treatments for all the patients, while at discharge, this index was lower in patients with moderate HR. Among these patients, QRS duration significantly decreased after treatment. Regarding survival, there was no

significant difference between survivors and nonsurvivors in terms of ECG changes.

Generally, ECG abnormalities are common among patients with HF and are related to poor outcomes. Widened QRS and prolonged PR are the most important abnormalities reported in recent studies. [40,41] According to these investigations, in-hospital mortality, death at discharge, readmission, and cardiac device implantation are among the poor outcomes observed in HF patients with ECG abnormalities. In this regard, Lund et al [42] concluded that QRS prolongation was an independent risk factor for all-cause mortality. In our study, the mean QRS duration at admission was similar to that in some previous research. [43,44] Irrespective of HF severity, QRS duration significantly decreased in all the patients after routine treatment and at discharge. Considering the severity of HF, QRS duration was similar between patients with moderate and severe HF at admission and discharge. One of the noteworthy results of the present study was the reduced QRS duration among patients with moderate HF at discharge. In other words, patients with moderate HF exhibited a better response to routine treatments than those with severe HF.

Prolonged PR interval represents another significant ECG abnormality. Prolonged baseline PR interval is associated with mortality. In patients with HF, prolonged PR interval reflects a spectrum of electrophysiological abnormalities, ranging from atrial enlargement to abnormalities necessitating pharmacological interventions. [16] According to a study by Nikolaidou et al, [22] there exists a relationship between PR interval and survival outcomes. Additionally, Chang et al [20] demonstrated a significant association between PR interval and cardiovascular mortality and morbidity. Conversely, the present findings indicated that PR interval did not exhibit a significant change from admission to discharge in any of the patients, irrespective of HF severity. Furthermore, a comparison between survivors and nonsurvivors revealed no significant association between PR interval and survival outcomes. While the small sample size of the current study was stated as the main reason for the discrepancy with previous findings on the association between PR interval and survival in HF patients, several other potential factors may have contributed. These include differences in the definitions and measurement methods of PR interval across studies, which could lead to variations in the observed associations. Moreover, the timing of the PR interval measurement during the course of HF may be crucial (we assessed it at admission and discharge), while other studies may have evaluated it at different time points or followed patients for a longer duration. Variations in treatments or interventions used to manage HF could potentially influence PR interval or its relationship with outcomes. Further, the duration of follow-up for assessing outcomes, such as mortality and morbidity, may differ among studies, potentially affecting the observed associations. Finally, unmeasured or unaccounted-for confounding factors, such as comorbidities, medications, and lifestyle factors, could have influenced the relationship between PR interval and outcomes in the study population.

Additionally, Arsenos et al [45] extracted T-wave alternans (TWA) from a 30-minute Short Resting Holter ECG (SRH ECG) recording in the supine position as a predictor of total mortality in HF. They concluded that TWA derived from SRH ECG might be present in severe cases of HF, even at a slow resting HR, and this index was found to be an important independent predictor of total mortality. Overall, SRH ECG recording represents an efficient and rapid method for the evaluation of HF patients. In this study, QT interval was a

poor predictor of patient outcomes, [46] and in the present study, no clear difference between QT interval and severity of HF was seen.

Relevant studies have reported that elevated HR is a risk factor for mortality and morbidity and associated with poor outcomes in patients with HF. [47] Conversely, decreasing HR is indicative of the therapeutic effect of treatment on HF. [48] The results of the present study are consistent with previous research findings. [49] HR decreased significantly after treatment in all the patients; this trend was more pronounced in patients with moderate HF. Notably, the HR of these patients was significantly lower than that of patients with severe HR at discharge.

In the current study, the hospital stay duration for severe HF cases was nearly 2 days longer than that of patients with moderate HF, and this difference was statistically significant. Considering the number of patients, 84% of severe HF cases may be hospitalized for more than 5 days for decompensation. Therefore, patients would probably be hospitalized for less than a week, around 6 days on average, when admitted for treatment. Research evidence demonstrates that a longer hospital stay is associated with poor prognostic factors, such as higher HR, lower systolic blood pressure, and decreased LVEF. [50] These findings are consistent with our results. In this study, patients with severe HF (decreased LVEF) had a history of admission and a longer hospital stay than those with moderate HF.

A notable limitation lies in the small number of deceased patients, which severely constrains the statistical power and generalizability of analyses examining changes in ECG indices from admission to discharge in relation to patient survival status. The paucity of events in this subgroup raises concerns about the risk of spurious findings and limits the extent to which the results can be extrapolated to broader populations. Inherent susceptibility to sampling bias due to the limited sample size restricts the inferential validity and external validity of such comparisons. Consequently, conclusions drawn from these analyses must be interpreted with extreme caution and viewed as preliminary findings requiring corroboration from larger, more rigorously designed studies with adequate statistical power to reliably evaluate survival-related ECG changes. In addition to the small sample size, the study was further constrained by the short follow-up duration and restricted access to patients following discharge, hampering the assessment of longer-term outcomes. Unmeasured confounding factors beyond the investigators' control may have influenced the ECG results, further compromising the internal validity of the findings.

CONCLUSIONS

In this study, widened QRS, prolonged PR, and increased HR were associated with the poor outcomes of HF patients. Normal ECG findings or improvement of ECG indices after treatment were associated with improved outcomes in patients with HF. Baseline QRS duration, PR interval, and HR could be used to enhance physicians' clinical decisions, especially in emergency cardiology departments. Furthermore, patients with moderate HF were expected to have a shorter hospital stay and better outcomes; they also responded well to routine treatments. However, further studies with a large sample size and longer follow-ups are suggested.

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