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Electrocardiography changes and different stages of heart failure in central Iran: A cross-sectional study from Yazd Health Study

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Abstract

Background and Aims: Electrocardiography (ECG) is a widely accessible, non-invasive, and cost-effective diagnostic instrument used to evaluate patients with suspected heart failure (HF). The aim of this study is to investigate electrocardiographic changes in patients with different stages of HF in a random population of Yazd city.

Methods: This prospective cross-sectional study included 319 individuals, randomly selected, aged 40 years and more, registered in the Yazd Health Study was conducted from March 2022 to May 2023 at Afshar Hospitals. In accordance with the AHA/ACC guidelines, HF was classified into four stages (A, B, C, and D).

Results: The 159 individuals were classified in the stage 0 group, 77 were in Stage A, 65 were in Stage B, and 18 were in Stage C of HF. In the Stage 0, the PR interval (PRi) was 130.5 ± 18.1 ms, while in Stage C, it was 143.3 ± 21.9 ms, with a significant difference ($p = 0.047$). Similarly, the QRS interval (QRSi) increased with HF staging ($p = 0.001$). The frequency of diabetes mellitus (DM), hypertension (HTN), hyperlipidemia (HLP), chronic heart disease, alcoholism, and PRi, QRSi, QT interval levels were independent predictors of HF stage in multivariate regression analysis.

Conclusion: The prevalence of HF stages, as classified by the AHA/ACC guidelines, was observed, with significant correlations between ECG parameters and HF progression. abnormal rhythms, left bundle branch block, ischemia, hypertrophy, and left atrial enlargement increased with higher HF stages. Major risk factors like DM and HTN exhibited a heightened prevalence in advanced HF stages, accentuating their pivotal role in the progression of HF.

KEYWORDS
electrocardiographic, heart failure, Iran, prevalence

1 | INTRODUCTION

Heart failure (HF) is a common and debilitating condition that affects millions of people around the world. It is characterized by the inability of the heart to pump sufficient blood to meet the metabolic needs of other organs.[1–3] Multiple underlying conditions and risk factors, including myocardial ischemia (MI), hypertension (HTN), and valvular heart disease, can cause HF.[4–6] The prevalence of HF is on the rise due to the aging of the population, the increasing prevalence of comorbidities and risk factors, and prolonged survival after myocardial infarction.[7] The 50% of medical admissions to general hospitals in North America are due to HF, which is associated with an acute in-hospital mortality rate of 12% and a 1-year mortality rate of 20%–35%.[8,9] Over 60% of patients with HF who are discharged from the hospital will be readmitted within 1 year.[10]

Given the high morbidity, mortality, and healthcare costs associated with HF, HF prevention is a top priority for public health. In this context, knowledge of the prevalence of preclinical precursors of HF in the population is a fundamental requirement for screening and prevention of this disease. The American Heart Association/American College of Cardiology (AHA/ACC) has classified HF into three stages (A, B, C/D), two of which are preclinical phases (A and B). Insufficient information has been discovered about the burden of HF stages on society and the mortality risk associated with these stages.[11,12] Therefore, diagnosis and classification of HF stages in the community are crucial for appropriate patient management and outcome improvement.

Electrocardiography (ECG) is a widely accessible, noninvasive, and cost-effective diagnostic instrument used to evaluate patients with suspected HF.[13] Several diagnostic guidelines, including the European Society of Cardiology and the National Institute for Clinical Excellence,[5] recommend the 12-lead ECG for diagnosing HF. The resting ECG can detect a variety of abnormalities that may contribute to the etiology and severity of HF.[14,15] 24-hourHolter ECG monitoring provides additional information that may be useful in the diagnosis and management of HF.[16] The aim of this study is to investigate electrocardiographic changes in patients with different stages of HF in a random population of Yazd city. Following the progression of HF disease and diagnosing HF stages based on ECG can be made easier for physicians and specialists who work in centers with fewer diagnostic equipment.

2 | MATERIALS AND METHODS

2.1 | Study population

This prospective cross-sectional study included 319 individuals, randomly selected, aged 40 years and more, registered in the Yazd Health Study (YaHS) was conducted From March 2022 to May 2023 at Afshar Hospitals, a university-affiliated tertiary medical center in Yazd. The participants were invited to this medical center to perform echocardiography and ECG. The exclusion criteria were pregnancy and patients with advanced forms of cancer. The YaHS participants were randomly included in the study. YaHS is a prospective study aimed at determining the prevalence of noncommunicable diseases and associated risk factors in the Greater Yazd Area. The methodology details were published elsewhere. In an overview, the YaHS population frame consisted of Yazd Greater Area adults aged 20–69. The 10,000 participants (200 clusters of 50) were selected using a two-step cluster sampling procedure.[17]

2.2 | Electrocardiogram evaluation

All subjects were evaluated using a standard 12-lead ECG and two-dimensional echocardiography. A trained clinical assistant utilized a Bionet Cardiocare EKG-2000 machine to record the ECGs. All ECGs were recorded using the standard calibration of 25 millimeters per second. PR interval (PRi)/QT interval (QTi)/QRS interval (QRSi), rhythm type, heart rate, the presence of fragmented QRS (fQRS), bundle branch block, poor r-wave progression (PRWP), hypertrophy, and left atrial enlargement (LAE) were analyzed on the 12-lead ECG.[7,18]

2.3 | Stages of HF and echocardiography evaluation

All patients underwent echocardiography using a VIVID 4 ultrasound system device (GE Medical Systems). The procedure was carried out and measurements were taken according to the guidelines of the American Society of Echocardiography. To corroborate the diagnosis of HF, a brief medical history and physical exam were performed. The definition of HF from the European Society of Cardiology was adopted.[19]

In accordance with the AHA/ACC guidelines, HF was classified into four stages (A, B, C, and D). In contrast, the stage 0 group consisted of asymptomatic individuals devoid of major risk factors for HF, including metabolic syndrome and obesity, HTN, diabetes mellitus (DM), exposure to cardio toxic agents, positive family history of cardiomyopathy and atherosclerotic cardiovascular disease, and any cardiac structural or functional abnormalities. This methodological approach provides a systematic and standardized method for distinguishing between various stages of HF, while ensuring that the stage 0 group is representative of a healthy population.[20,21]

2.4 | Ethical considerations

The study was approved by the ethical committee of Shahid Sadoughi University of medical sciences (IR. SSU. MEDICINE. REC.1400.117); all study procedures were conducted according to the Declaration of Helsinki; and informed consent was obtained from all patients before the study.

2.5 | Statistical analysis

The SPSS version 20 for Windows (SPSS Inc.) software package was used to analyze all the data. Qualitative variables were presented with frequency and percentage and compared between groups by chi-square test. ANOVA test was used to compare quantitative variables that are expressed with mean ± standard deviation. Pearson's correlation was used to analyse correlates HF stages. Multivariate regression analysis was applied to determine the independent predictors HF stages. A two-sided $p < 0.05$ was considered significant.

3 | RESULTS

Among the 319 participants included in the study, 159 individuals were classified in the stage 0 group, 77 were in Stage A, 65 were in Stage B, and 18 were in Stage C of HF. Stage A and Stage C had a significantly higher mean age for participants than the Stage 0 group and Stage B ($p = 0.001$). The frequency of DM, HTN, hyperlipidemia (HLP), and chronic heart disease in Stage A group was significantly higher than in other groups ($p < 0.001$). Moreover, the prevalence of alcoholism was significantly higher in Stage A and Stage B compared to the stage 0 and Stage C ($p = 0.004$). (Table 1).

The majority of participants displayed a sinus rhythm. There were no statistically significant differences in heart rate (HR) among the stages ($p = 0.053$). The PRi increased as the HF stage progressed. In the Stage 0, the average PRi was 130.5 ± 18.1 ms, while in Stage C, it was 143.3 ± 21.9 ms, with a significant difference ($p = 0.047$). Similarly, the QRSi increased with HF staging. The mean QRSi was 86.1 ± 11 ms in the Stage 0 and 101.1 ± 19.9 ms in Stage C, with a significant difference ($p = 0.001$). The prevalence of right bundle branch block (RBBB) was higher in Stage A (11.7%) compared to the Stage 0 (3.8%), while left bundle branch block (LBBB) was more prevalent in Stage C (38.8%) compared to the other stages ($p = 0.001$). Ischemia and hypertrophy were significantly associated with HF staging ($p = 0.001$). The prevalence of LAE increased from 3.8% in the Stage 0%–22.2% in Stage C ($p = 0.014$). The prevalence of PRWP increased from 1.3% in the Stage 0%–11.1% in Stage C ($p = 0.032$) (Table 2).

Correlation analyses revealed significant associations between major risk factors, such as DM and HTN and HF progression. ECG parameters, including PRi, QRSi, and QTi, and ischemia, hypertrophy, and atrial enlargement demonstrated a progressive increase with higher HF stages (Table 3). Among the mentioned variables, those that were independent predictors of HF stage in multivariate regression analysis are shown in the table (Table 4).

4 | DISCUSSION

HF is a major public health concern. HF continues to have a significant annual mortality rate despite therapeutic advancements and improved survival rates in recent decades. Electrocardiograms are recommended for all patients with suspected HF, according to current guidelines.[22,23] An abnormal ECG has a relatively high sensitivity of 89% for diagnosing HF, but only a moderate specificity of 56%, showing that HF is extremely unlikely in the presence of a normal ECG.[24] In the present study, we examined changes in ECG in different stages of HF in the general population of Yazd city. 49.8% of the individuals in the general population had stage 0, 24.1% had stage A, 20.4% had stage B, and 5.6% had stage C of HF. In a cohort study by Ammar et al., 32% of the population over 45 years old was in stage 0, 22% in stage A, 34% in stage B, 12% in stage C, and 0.2%

TABLE 1 Baseline characteristics of patients with HF and stage 0 group.

	Total	Stage 0 *N* = 159	Stage A *N* = 77	Stage B *N* = 65	Stage C *N* = 18	*p* value
Age (years)	56.4 ± 9.2	54.8 ± 8.7	60.6 ± 8.5	54.7 ± 9.5	58.8 ± 9.7	<0.001*
Sex, male, *n* (%)	186 (58.3%)	93 (58.5%)	37 (48.1%)	43 (66.2%)	13 (72.2%)	0.09**
DM, *n* (%)	69 (21.6%)	0	47 (61%)	16 (24.6%)	6 (33.3%)	<0.001**
HTN, *n* (%)	76 (23.8%)	0	55 (71.4%)	17 (26.2%)	4 (22.2%)	<0.001**
HLP, *n* (%)	75 (23.5%)	19 (11.9%)	34 (44.2%)	16 (24.6%)	6 (33.3%)	<0.001**
BMI kg/m²	28.1 ± 4.3	27.6 ± 4.4	29 ± 4	27.8 ± 4.7	29.7 ± 3.3	0.04*
Chronic heart disease, *n* (%)	28 (8.8%)	0	13 (16.9%)	8 (12.3%)	7 (38.9%)	<0.001**
Thyroid disorders, *n* (%)	18 (5.6%)	6 (3.8%)	9 (11.7%)	2 (3.1%)	1 (5.6%)	0.07**
Smoking, *n* (%)	48 (15%)	22 (13.8%)	9 (11.7%)	16 (24.6%)	1 (5.6%)	0.08**
Alcoholism, *n* (%)	7 (2.2%)	0	2 (2.6%)	5 (7.7%)	0	0.001**

Note: Data are expressed as mean ± SD or *n* (%).

*One-way ANOVA was used.

**Chi-squared test was used.

TABLE 2 ECG parameters and HF staging.

		Stage 0 *N* = 159	Stage A *N* = 77	Stage B *N* = 65	Stage C *N* = 18	*p* value
Rhythm, *n* (%)	sinus	155 (97.5%)	68 (88.3%)	63 (96.9%)	16 (88.9%)	0.01**
	Nonsinus	4 (2.5%)	9 (11.7%)	2 (3.1%)	2 (11.1%)	
HR (b/min)		70.4 ± 8.1	73 ± 9.5	70.8 ± 9.8	67.2 ± 8.7	0.053*
Axis, *n* (%)	Right	3 (1.9%)	0	1 (1.5%)	2 (11.1%)	0.02**
	Left	8 (5%)	7 (9.1%)	7 (10.8%)	3 (16.7%)	
PRi (ms)		130.5 ± 18.1	130.6 ± 18.2	133.8 ± 22.3	143.3 ± 21.9	0.047*
QRSi (ms)		86.1 ± 11	92.2 ± 13.4	91.5 ± 14.2	101.1 ± 19.9	<0.001*
QTi (ms)		398.5 ± 10.9	397.9 ± 8.9	395 ± 15	393.3 ± 15.3	0.1*
Conduction abnormality, *n* (%)	RBBB	6 (3.8%)	9 (11.7%)	3 (4.6%)	1 (5.6%)	<0.001**
	LBBB	0	7 (9.1%)	5 (7.7%)	7 (38.8%)	
Ischemia, *n* (%)		10 (6.3%)	3 (3.9%)	4 (6.2%)	7 (38.9%)	<0.001**
Hypertrophy, *n* (%)		5 (3.1%)	13 (16.9%)	12 (18.5%)	2 (11.1%)	0.001**
fQRS, *n* (%)		7 (4.4%)	4 (5.2%)	4 (6.2%)	1 (5.6%)	0.95**
LAE, *n* (%)		6 (3.8%)	5 (6.5%)	3 (4.6%)	4 (22.2%)	0.01**
PRWP, *n* (%)		2 (1.3%)	1 (1.3%)	1 (1.5%)	2 (11.1%)	0.03**

Note: Data are expressed as mean ± SD or *n* (%).

Abbreviations: fQRS, fragmented QRS; HR, heart rate; LAE, left atrial enlargement; LBBB, left bundle branch block; PRi, PR interval; PRWP, poor R wave progression; QRSi, QRS interval; QTi, QT interval; RBBB, right bundle branch block.

*One-way ANOVA was used.

**Chi-squared test was used.

TABLE 3 Correlates of the variables with heart failure stages.

	r	*p* value
DM	0.326	<0.001
HTN	0.302	<0.001
HLP	0.177	0.002
Chronic heart disease	0.317	<0.001
Alcoholism	0.14	0.01
PRi	0.129	0.02
QRSi	0.267	<0.001
QTi	−0.133	0.02
Ischemia	0.155	0.005
Hypertrophy	0.186	<0.001
LAE	0.119	0.03

TABLE 4 The finding of multivariate regression analysis.

	β	CI 95%	*p* value
DM	0.18	0.68 to 0.15	0.001
HTN	0.15	0.6 to 0.82	0.01
Chronic heart disease	0.16	0.91 to 0.2	0.001
Alcoholism	0.17	1.75 to 0.5	<0.001
PRi	0.1	0.001 to 0.01	0.04
QRSi	0.12	0.001 to 0.016	0.02
QTi	−0.14	−0.019 to −0.004	0.001

in stage D.[25] In a separate, Jorge et al. classified participants aged 45 and older as stage 0 11.7%, stage A 36.6%, stage B 42.6%, and stage C 9.3%. Prevalence estimates differ depending on the methods used to measure ventricular function, the classification cutoff used to define low LVEF (30%–54%), the clinical criteria used to define "asymptomatic," and the characteristics of the study population.[26] In addition, most of these studies have investigated the phases of HF in populations with a higher risk of HF.

In the current study, the frequency of nonsinusoidal rhythm, left axis deviation (LAD), left bundle branch block (LBBB), evidence in favor of ischemia, hypertrophy, LAE, and poor R wave progression was significantly increased in high stages of HF compared to stage 0.

To date, ECG has only been compared between individuals with and without HF. 98.2% of HF patients had abnormal ECG, with left ventricular hypertrophy (LVH) being the most prevalent ECG abnormality among patients with reduced LVEF.[18] According to Omotosho et al.'s study, LVH was the most common ECG abnormality among 68% of HF patients.[27] In the present study, ventricular and atrial hypertrophy were significantly higher in patients with stages A and B compared to individuals with stage 0, and the progression of cardiac stages was correlated with hypertrophy.

Obviously, it should be clarified that ventricular and atrial hypertrophy were not discussed separately in this study.

James et al. stated that QRSi and QTi are significantly higher in HF patients compared to the control group. ECG changes in favor of previous MI, intraventricular conduction disorder, abnormal axis, ventricular hypertrophy, and atrial fibrillation (AF) were significantly more in patients with HF. This study showed that ECG can provide primary care physicians with the ability to accelerate the diagnosis of HF to initiate more relevant research and treatment in the community. ECG is a useful test for predicting HF in the community, which can increase its predictive power by adding other variables, such as NT-proBNP.[28] In contrast, Khan et al. claimed that most of the ECG findings in these patients are nonspecific and alone are not accurate for diagnosing or eliminating specific cardiac abnormalities in patients with acute HF.[13] Dzudie et al. demonstrated that the high prevalence of ECG abnormalities is probably because a significant number of these patients suffer from comorbidities such as HTN and DM.[5]

In this study, the frequency of major risk factors, such as DM, HTN, HLP, and chronic heart disease was significantly higher in patients with HF. In addition, these factors were independent predictors of HF stages in multivariate regression analysis. Samuel et al. also showed in the CARDIA cohort study that DM and HTN are more frequent in the high stage of HF. It is hypothesized that co-morbidities are associated with increased ECG abnormalities in HF patients.[29] The prognostic significance of LVH among hypertensive patients is well established. Hypertensive heart disease predisposes to the development of LVH, cardiac arrhythmia, HF, MI, left atrial abnormalities, and functional valvular regurgitation. KAMILU et al. found that AF is the most common arrhythmia (affecting 16% of all patients).[18] Opadijo and Omotosho also found AF in 7.3% of HF patients with reduced LVEF.[27] In the present study, nonsinusoidal rhythms are more common in patients with HF, and it is approximately 11% in A and C stages. In a previous study, LAD was found in 16.9% of patients with HF, and LBBB was found in 8.5% of patients with reduced LVEF. LBBB is an important finding in patients with HF, as it is associated with worsening HF symptoms and LV systolic function, as well as increased mortality.[18] In addition, Lip et al. stated that high doses of thiazide diuretics commonly used to treat HTN may lead to electrolyte abnormalities (e.g., hypokalemia, hypomagnesemia) that further contribute to arrhythmias.[30] Sundström et al. concluded in a prospective longitudinal cohort study, HLP, as well as HTN and obesity, at age 50 years predicted the prevalence of LVH 20 years later.[31] Gupta et al. reported that the most common abnormality observed in patients with DM was ST elevation, followed by LAE, LVH, and BBB.[32] Dzudie et al. stated that the high prevalence of ECG abnormalities is probably because a significant number of these patients suffer from comorbidities such as HTN and DM.[5]

5 | LIMITATIONS

The present study has several limitations. The most important thing is that we examined the ECG at rest, and the ECG after physical activity should also be examined in future studies. In addition, because of the type of current study and time limitations, the drugs used, long-term outcomes such as mortality and the number of hospitalizations were not evaluated.

6 | CONCLUSION

The prevalence of HF stages, as classified by the AHA/ACC guidelines, was observed, with significant correlations between ECG parameters and HF progression. abnormal rhythms, LBBB, ischemia, hypertrophy, and LAE increased with higher HF stages. Major risk factors such as DM and HTN exhibited a heightened prevalence in advanced HF stages, accentuating their pivotal role in the progression of HF. This study underscores the pivotal role of ECG as a diagnostic instrument for HF, facilitating the early detection and proficient management of HF. Further research considering additional variables and long-term outcomes is warranted to enhance our understanding of ECG changes associated with different stages of HF in the general population.

AUTHOR CONTRIBUTIONS

Sedighe Sadeghi: Conceptualization; methodology; data curation; writing–review and editing; writing–original draft; project administration. **Mojtaba Jokar**: Writing–original draft; writing–review and editing; project administration; investigation; methodology. **Seyed Mostafa Seyed Hossieni Tezerjani**: Resources; investigation; data curation; methodology. **Hasan Haghaninejad**: Writing–review and editing; supervision; visualization; conceptualization. **Elahe Zare**: Conceptualization; methodology; data curation; visualization. **Mahmood Emami Meybodi**: Supervision; data curation; investigation; software; methodology. **Mohammadtaghi Sareban hassanabadi**: Project administration; resources; writing–original draft; data curation; formal analysis; software. **Masoud Mirzaei**: Writing–review and editing; writing–original draft; methodology; validation; investigation. **Hamidreza Mohammadi**: Writing–original draft; writing–review and editing; formal analysis; data curation; visualization. **Forough Sadat Tabatabaei**: Writing–review and editing; writing–original draft; supervision; visualization; validation; investigation.

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CONFLICT OF INTEREST STATEMENT

The authors state that they have no conflicts of interest that might have influenced the outcome of this research.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

Approval was obtained from the ethics committee of Shahid Sadoughi University of Medical Sciences. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

TRANSPARENCY STATEMENT

The lead author Forough Sadat Tabatabaei affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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