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Electrographic Profile and their correlation in patients with Heart Failure- a cross-sectional study

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Abstract: Introduction: Heart failure (HF) is the final stage of most cardiac disorders, it remains one of the leading causes of morbidity and mortality globally. Heart failure (HF) with reduced ejection fraction (HFrEF), heart failure with preserved ejection fraction (HFpEF), and heart failure with mildly-reduced ejection fraction (HFmrEF) are the three subtypes of HF. The resting electrocardiogram (ECG) is a tool used in the early evaluation of patients with heart failure.

Methods: study design: this was a cross-sectional study over a period of 6 months from February 2024-July 2024 carried out in the Department of Medicine, Mahaveer Institute of Medical Sciences. Total of 50 cases of heart failure were included after confirming the inclusion and exclusion criteria. A standard 12-lead ECG, two-dimensional echocardiography was performed on all included subjects.

Results: Out of 50 patients, 33 were male. LVH was the most common abnormality seen in 52% of patients. LAD was seen in 48% patients with reduced EF and 7 % of the patients with preserved EF which was statistically significant (p value 0.023). Atrial fibrillation was found in 8 % patients. Complete LBBB was found in 17% patients with reduced EF. Poor R Wave Progression was seen in 31 % of patients with reduced EF, 29% of mildly-reduced and 7 % of preserved EF. QTc was prolonged in in total 18 (36%) patients.

Conclusion: ECG is a simple, easily available tool for diagnosing HF. It is almost always abnormal in heart failure, and most patients had at least three abnormalities. In addition, HF patients with LVEF < 40% had more ECG abnormalities. We highlight the significance of accurately analyzing the ECG for subtle features that are likely to being overlooked. ECG is a non-invasive method that can be utilized as an early warning for acute HF decompensation in the outpatient setting. It can predict long term mortality and readmission risk. In patients with dyspnea of unclear etiology, the ECG data further corroborates the biomarker results and the diagnosis of HF.

Keywords: Congestive Heart Failure, Ventricular Ejection Fraction, ECG, 2D Echocardiography

Introduction: Heart and blood vessel disorders, such as coronary heart disease, cerebrovascular disease, arterial disease, rheumatic heart disease, congenital heart disease, deep vein thrombosis, and pulmonary embolism, are together referred to as cardiovascular diseases (CVD). Heart failure (HF) is the final stage of most cardiac disorders, it remains one of the leading causes of morbidity and mortality globally. HF is a multifactorial clinical condition defined by the heart's diminished capacity to pump and/or fill with blood. (1)

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While coronary artery disease is the primary cause of HFrEF, it has been observed that patients with HFpEF are more likely to be female, older, obese, and have a higher New York Heart Association (NYHA) class. Additionally, patients with HFpEF are more likely to have cardiovascular and non-cardiovascular comorbidities, including anemia, chronic kidney disease, chronic pulmonary disease, hypothyroidism, cancer, peptic ulcer, and psychiatric disorders. (2)

Heart failure has been classified into three subtypes: heart failure with reduced ejection fraction (HFrEF), heart failure with preserved ejection fraction (HFpEF), and heart failure with mildly reduced ejection fraction (HFmrEF). These subtypes are based on the ejection fraction (EF), the presence of structural heart disease, and diastolic dysfunction. It is now acknowledged that HFmrEF is a separate entity, with features that fall somewhere between those of HFpEF and HFrEF. The European Society of Cardiology's (ESC) current guideline on Heart failure suggests classifying patients according to their EF as a measure of the underlying mechanism: HF with reduced EF (EF < 40%), HF with mildly reduced EF (EF between 41% and 49%), and HF with intact EF (EF ≥ 50%) (3)

The resting electrocardiogram is a tool used in the early assessment of patients with heart failure (ECG). Its significance lies in its ability to detect a wide range of anomalies that may be related to the etiology and severity of heart failure, all while being non-invasive and simple to perform. (4) Several ECG characteristics as indicators of prognosis or acute decompensation. In patients with myocardial infarction, decreased EF, and heart failure, QT prolongation has been shown to be an independent predictor of overall mortality. In HF patients, T-wave alternations have demonstrated prognostic power for both hospitalization and cardiac death. (5)

The two currently recognized biomarkers for confirming the diagnosis of Acute Heart Failure (AHF), determining the prognosis, and monitoring the course of the illness are Brain natriuretic peptide (BNP) and N-Terminal prohormone of brain natriuretic peptide (NT-proBNP). The following values are necessary to diagnose AHF: NT-proBNP > 300 ng/L and BNP > 100 ng/L. Heart proteins called troponins (cTn) are located in the cytoplasm of cardiac myocytes and have a role in the contraction of the heart muscle by promoting the interaction of actin and myosin filaments. The most specific subunit for cardiac muscle is thought to be cTnI. Higher blood concentrations of creatine phosphokinase isoenzyme MB (CPK-MB) are associated with a greater degree of clinical severity in heart failure patients, demonstrating the usefulness of this biomarker as a predictive tool (6).

Materials and Methods: study design: this was a cross-sectional study over a period of 6 months from February 2024- July 2024 carried out in the Department of Medicine, Mahaveer Institute of Medical Sciences. Total of 50 cases of heart failure were included after confirming the inclusion and exclusion criteria. A standard 12-lead ECG, two-dimensional echocardiography (ECHO) was performed on all included subjects.

Inclusion criteria: (atleast 1)

1. Clinical diagnosis of heart failure during admission

2. Known diagnosis of heart failure at any time in last 3 years

Exclusion criteria:

1. Patients undergone cardiovascular procedures 3 months before screening.

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Definitions: Patients who fulfilled the Framingham criteria were evaluated for acute heart failure. Acute pulmonary edema on X-ray, orthopnea, paroxysmal nocturnal dyspnea, hepatojugular reflux, jugular vein distention, pulmonary rales, the presence of the third heart sound (gallop rhythm), and weight loss greater than 4.5 kg in five days in response to treatment are the main requirements. The following are considered minor criteria: tachycardia (heart rate > 120/min), nocturnal cough, hepatomegaly, ankle edema, and dyspnea on exertion. For the diagnosis, there must be two major criteria or one major criterion plus two minor factors. (6)

The ECG parameters were defined as follows (6):

- Left ventricular hypertrophy (LVH): patients that met the Estes criteria and Morris index (point score ≥ 5);
- QT interval correction (QTc) was done using the Fridericia (Hodges) formula;
- Poor R-wave progression (PRWP): RV3 or RV4 < 2 mm plus a drop in RV2 to RV3 or RV3 to RV4, RV3 < 1 mm plus < 0.25 mm increase from RV2 to RV3 (after LVH features are excluded);
- Left bundle branch block (LBBB): QRS duration > 120 ms, dominant S wave in V1, broad monophasic R wave in lateral leads (DI, aVL, V5, V6), Q wave not present in lateral leads, R wave peak duration > 60 ms in V5–V6;
- pathological Q wave: >40 ms wide (>1 mm), >2 mm deep, >25% of depth of QRS complex, seen in leads V1–V3;
- Complex premature ventricular contractions (PVC): presence of doublets, triplets or non-sustained ventricular tachycardia (NSVT).

Statistics: Data were analyzed using Stata Version 7. The categorical variables were expressed as frequencies (numbers) and percentages (%). The Fisher's exact tests were used to test for significance of observed associations between categorical variables. ANOVA was used for continuous variables. A *p*-value of < 0.05 was considered significant.

Results:

Out of 50 patients, 33 were male. The average age was 66 years. Based on left ventricular ejection fraction (LVEF), 29 patients had reduced ejection fraction, followed by 14 patients who had preserved ejection fraction and 7 patients had mildly-reduced ejection fraction. The most common complaint patients presented with was dyspnea on exertion in 88 %, followed by orthopnea, paroxysmal nocturnal dyspnea (PND) in 60%, pedal edema in 58%, chest pain in 48% of cases. The baseline characteristics of patients are presented in table1.

Table 1: Baseline characteristics of patients

Characteristics	LVEF > 50% n= 14 (%)	LVEF 41-49% n= 7 (%)	LVEF <40% n= 29 (%)	Total n= 50 (%)	P value
Age (mean, SD)	65±12	69±19	66±14	66±14	0.8742
Gender Female	4 (29)	2 (29)	11 (38)	17 (34)	0.914
Male	10 (71)	5 (71)	18 (62)	33 (66)	
Heart rate (mean, SD)	96±19	83±9	87±12	89±15	0.110
SBP (mean)	129±29	127±21	131±32	129±29	0.828

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Signs & symptoms:					
Chest pain	7 (50)	4 (57)	13 (45)	24 (48)	0.923
Dyspnea on exertion	11 (79)	7 (100)	26 (90)	44 (88)	0.815
Orthopnea, PND	5 (36)	1 (14)	24 (83)	30 (60)	0.046*
Pedal edema	6 (43)	4 (57)	19 (66)	29 (58)	0.367
Cough	2 (14)	2 (29)	3 (10)	7 (14)	0.010*
Palpitations	2 (14)	1 (14)	1 (3)	4 (8)	0.230
Hepatomegaly	2 (14)	1 (14)	4 (14)	7 (14)	1
Chest X Ray: Cardiomegaly	-	-	7 (24)	7 (14)	0.065
Addiction: Smoker	4 (29)	2 (29)	6 (21)	12 (24)	0.722
Alcohol	1 (7)	3 (43)	5 (17)	9 (18)	0.154
Tobacco	1 (7)	1 (14)	3 (10)	5 (10)	1
History of:					
Hypertension	5 (36)	2 (29)	13 (45)	20 (40)	0.560
Diabetes	2 (14)	1 (14)	13 (45)	16 (32)	0.090
Anemia	2 (14)	1 (14)	3 (10)	6 (12)	1
CAD	2 (14)	3 (43)	5 (17)	10 (20)	0.254
Nephropathy	-	1 (14)	2 (7)	3 (6)	0.524
DCMP	-	-	2 (7)	2 (4)	1
COPD	2 (14)	-	1 (3)	3 (6)	0.710
Atrial fibrillation	1 (7)	2 (29)	2 (7)	5 (10)	0.247
Thrombolysis	1 (7)	-	2 (7)	3 (6)	1
PTCA	1 (7)	-	3 (10)	4 (8)	1
CABG	-	-	2 (7)	2 (4)	1

Legend: LVEF: Left ventricular ejection fraction, n: number of patients, SBP: Systolic Blood Pressure, PND: paroxysmal nocturnal dyspnea, CAD: Coronary Artery Disease, DCMP: Dilated cardiomyopathy, COPD: Chronic obstructive pulmonary disease, PTCA: Percutaneous transluminal coronary angiography, CABG: Coronary Artery Bypass Graft

The corrected QT interval (QTc) was prolonged (defined as > 440 ms in males and > 460 ms in females) in total 18 (36 %) patients. Out of which, 5 (36%) had preserved LVEF, 3 (43%) mildy-reduced LVEF, 10 (34%) had reduced LVEF. (p=0.919) Mean QTc in patients with LVEF>50% was 444±84ms, in patients with LVEF 41-49% was 456±120 ms, and in patients with LVEF <40% was 456±62 ms. The other ECG abnormalities are listed in table 2.

Table 2: ECG abnormalities

ECG abnormality	LVEF > 50% n= 14 (%)	LVEF 41-49% n= 7 (%)	LVEF <40% n= 29 (%)	Total n= 50 (%)	P value
LVH	5 (36)	3 (43)	18 (62)	26 (52)	0.267
LAE	1 (7)	1 (14)	2 (7)	4 (8)	0.778
Sinus Tachycardia	1 (7)	1 (14)	8 (28)	10 (20)	0.333
LAD	1 (7)	3 (43)	14 (48)	18 (36)	0.023*
AF	1 (7)	1 (14)	2 (7)	4 (8)	0.778
PVC	1 (7)	1 (14)	4 (14)	6 (12)	1
APC	1 (7)	1 (14)	3 (10)	5 (10)	1
RAD	2 (14)	-	-	2 (4)	0.091
ST segment abnormality	6 (43)	2 (29)	11 (38)	19 (38)	0.841

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T inversion	8 (57)	2 (29)	15 (52)	25 (50)	0.904
Pathological q wave	1 (7)	1 (14)	4 (14)	6 (12)	0.701
Complete LBBB	1 (7)	1 (14)	5 (17)	7 (14)	0.849
Poor R wave Progression	1 (7)	2 (29)	9 (31)	12 (24)	0.207
AMI	2 (14)	2 (29)	3 (10)	7 (14)	0.444

Legend: LVEF: left ventricular ejection fraction; n: number of patients; LVH: left ventricular hypertrophy; LAE: left atrial enlargement; LAD: left axis deviation; AF: atrial fibrillation; PVC: Premature ventricular contraction, APC: Atrial premature complexes, RAD: right axis deviation; LBBB: left bundle branch block; RBBB: right bundle branch block; BAE: bilateral atrial enlargement; AMI: acute myocardial infarction.

Dilated cardiomyopathy was found exclusively in reduced LVEF (statistically significant p 0.032). Other rare causes of heart failure with preserved EF included cor-pulmonale, anemia (Table 3)

Table 3: Types and Etiology of Heart Failure

Diagnosis	LVEF > 50% n= 14 (%)	LVEF 41-49% n= 7 (%)	LVEF <40% n= 29 (%)	Total n= 50 (%)	P value
IHD	6 (43)	5 (71)	17 (59)	28 (56)	0.475
DCM	-	-	8 (26)	8 (16)	0.032*
RHD	1 (7)	1 (14)	1 (3)	3 (6)	0.524
HHD	2 (14)	1 (14)	2 (7)	5 (10)	0.517
Other	5 (36)	-	1 (3)	6 (12)	0.009*

Legend: LVEF: Left ventricular ejection fraction; n: number of patients; HHD: hypertensive heart disease; RHD: rheumatic valvular heart disease; DCM: dilated cardiomyopathy; IHD: ischemic heart disease.

Table 4: Laboratory Parameters

Parameters	Total
Hemoglobin (g/dl) (mean, SD)	12±2
Leucocytes (thous/cumm) (mean, SD)	9000±3149
Platelets (lac/cumm) (mean, SD)	2±0.6
RBS (mg/dl) (mean)	109
Urea (mg/dl) (mean, SD)	40±22
Creatinine (mg/dl) (mean, SD)	1.2±0.7
LDL-c (mg/dl) (n=30) (mean)	86
HDL-c (mg/dl) (n=30) (mean)	45
TG (mg/dl) (n=30) (mean)	150
Bilirubin (mg/dl) (mean)	1.02
CPKMB (U/L) (n=13)	6.48
NT-Pro BNP (ng/L) (n=15) (mean)	4629
Troponin I positive (n)	7

Legend: RBS: Random Blood Sugar, LDL: Low density lipoprotein, HDL: high density lipoprotein, TG: triglyceride, CPKMB: creatine phosphokinase isoenzyme MB NT-Pro BNP: N-Terminal prohormone of brain natriuretic peptide

Discussion:

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Multi-systemic and related comorbidities, including anemia, renal failure, atrial fibrillation, depression, and chronic obstructive pulmonary disease, are predisposed to develop in patients with heart failure (HF). Hypertension is thought to be the most closely associated multisystemic condition with HF and a comorbidity that causes HF. (7) In our study, 32% of patients had diabetes, and 40% of patients had hypertension. A percentage of 12% had severe anemia. Anemia is frequently found in heart failure patients, and it increases their mortality rate. An improved quality of life results from treating anemia. (8) There was little variation in LVEF between preserved, mildly reduced, and reduced, with an average age of 66 years and a male preponderance of 66%.

There was history of smoking in 24% of patients, alcohol in 18% and tobacco chewing in 10% of patients in our study. Patients with preserved ejection fraction had significantly lower rates of other modifiable cardiac risk factors, including smoking, diabetes as compared to reduced LVEF. Lifestyle is a predisposing factor for cardiovascular diseases. Inadequate habits such as sedentarism, alcohol consumption, smoking, inadequate eating led to increase in cardiovascular diseases (9). Rate of thrombolysis, PTCA and CABG was also lower in patients with preserved LVEF. Among the presenting signs and symptoms, patients with preserved LVEF had lower rates of chest pain, SOB, orthopnea, PND, pedal edema, hepatomegaly as compared to reduced LVEF. Orthopnea was seen in 83% patients with reduced LVEF which was statistically significant (p 0.046). Our results are consistent with a research by Bhatia et al. that found that patients with maintained ejection fraction had higher rates of pedal edema and reduced rates of acute pulmonary edema, paroxysmal nocturnal dyspnea. Patients with preserved ejection fraction also had lower rates of peripheral vascular disease, angina, prior myocardial infarction, and prior coronary-artery bypass surgery. (10)

Overall LVH was the most common abnormality seen in 52% of patients. LVH on ECG was seen in 62% of patients with reduced EF and 36% with preserved EF. LVH was the common abnormality seen in patients with reduced EF in a study done by Opadij et al. (11) A high prevalence of hypertension can lead to development of LVH. Hypertensive heart disease predisposes to the development of left ventricular hypertrophy, cardiac arrhythmia, heart failure, myocardial ischemia, left atrial abnormalities and functional valvular regurgitation. (12)

A statistically significant (p value of 0.023) left axis deviation was seen in 48% of patients who had reduced LVEF and 7% of patients with preserved LVEF. According to a study by Karaye et al., LAD can be used as a pre-diagnostic marker for heart failure. Among patients with decreased LVEF ($p = 0.035$), the prevalence of LAD was found in 16.9% of all patients. (4)

In our study, 28% of individuals with decreased LVEF had sinus tachycardia. This study has similarities to those of Thomas et al., who found that patients who had reduced LVEF had higher rates of LVH, LAE, and sinus tachycardia ($p = 0.002$, 0.001, and 0.004, respectively). (13) Of the arrhythmias, 8% of patients had atrial fibrillation. Usually, the most prevalent arrhythmia observed in heart failure patients is atrial fibrillation. (4) Owan et al. found AF in 41.3% of HF patients who had reduced LVEF and 28.5% of those with normal LVEF ($p < 0.001$). For individuals with heart failure with preserved ejection fraction, atrial fibrillation is frequently the cause of acute decompensation. (14)

Complete LBBB was found in 17% patients with reduced EF. This finding is similar to a study by Karaye et al, where complete LBBB was found in 8.5% of patients with reduced LVEF. (4) Left bundle branch block is an important finding in patients with heart failure, because of its association with worsening of

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HF symptoms and LV systolic function, as well as increased mortality. LBBB prevalence in heart failure is higher as compared to general patient population. (15)

In 14% of individuals with decreased EF, pathological q wave was seen. Prior myocardial infarction is usually linked to a pathological Q wave. It indicates the ischemic etiology of heart failure and helps predict unfavorable outcomes concurrently. Pathological Q waves indicate a poor prognosis. Pathological Q wave was found to correlate with NT-proBNP levels in a research by Chetran et al., supporting the possibility that it is a sign of HF decompensation. (6)

Poor R Wave Progression was seen in 31 % of patients with reduced EF, 29% of mildly-reduced and 7 % of preserved EF. Poor R wave is associated with adverse prognosis in general population and with sudden cardiac death in patients with coronary artery disease (6). It has a prognostic role in predicting all-cause and cardiovascular mortality. (16) Overall, 38% of patients had ST changes and 50% of patients had T inversions. ST-T changes are a predictor of cardiovascular mortality. Acute MI was seen in 7 patients. Heart failure (HF) is a severe complication of acute ST-segment elevation myocardial infarction (STEMI) (17)

Out of all the patients, 18 (36%) had a prolonged QTc. Three (43%) had mildly reduced LVEF, five (36%) had a preserved LVEF, and ten (34%) had a reduced LVEF (p=0.919, not significant). QTc was prolonged in 71.4 and 78.9% of HF patients with preserved and reduced LVEF, respectively, in a study by Karaye et al. However, the difference was not statistically significant (p = 0.370). (4) QTc prolongation is an ECG parameter used to assess the risk for malignant ventricular arrhythmias. It is also associated with torsade de pointes and increased mortality. (6) QT prolongation is an independent predictor of overall mortality in individuals with heart failure, reduced EF, and myocardial infarction. T-wave alternations are a predictive marker for cardiac mortality and hospitalization in patients with heart failure. (18–19)

Dilated cardiomyopathy was found exclusively in reduced LVEF 8 (26%) patients. Ischemic heart disease was seen in 59% of patients with reduced LVEF, 43% in preserved LVEF and 71% patients of mildly-reduced LVEF. Other rare causes of heart failure with preserved EF included cor pulmonale, anemia was seen in 12% of patients. Mean NT-ProBNP was 4629 ng/L, Troponin was positive in 7 people in our study. NT-ProBNP is a marker for diagnosis as well as prognosis. Biomarkers like NT-Pro BNP, Troponin level, Serum Creatinine level are predictors of re-hospitalization of acute heart failure patients. (6)

Conclusion: ECG is a simple, easily available tool for diagnosing HF. It is almost always abnormal in heart failure, and most patients had at least three abnormalities. In addition, HF patients with LVEF < 40% had more ECG abnormalities. LVH was the most common abnormality overall, whereas left axis deviation was found more in patients with reduced EF, which was statistically significant. We highlight the significance of accurately analyzing the ECG for subtle features that are likely to being overlooked. ECG is a non-invasive method that can be utilized as an early warning for acute HF decompensation in the outpatient setting. It can predict long term mortality and readmission risk. In patients with dyspnea of unclear etiology, the ECG data further corroborates the biomarker results and the diagnosis of HF.

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