

RESEARCH ARTICLE

# Efficacy of Electrocardiographic Findings for Prediction of Moderate to Severe Pulmonary Hypertension in Patients with Mitral Stenosis

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## ABSTRACT

**Background:** Mitral stenosis (MS) is the most common valvular heart disease throughout the world. Pulmonary hypertension is an important and grave hemodynamic consequence of mitral stenosis. Persistent pulmonary hypertension leads to increase right heart pressure, Right Ventricular Hypertrophy (RVH) and subsequently right heart failure. There are various electrocardiographic parameters and criteria of Right Ventricular Hypertrophy (RVH) for diagnosis of pulmonary hypertension in various disease. Different ECG parameters and criteria of Right Ventricular Hypertrophy (RVH) have different predictive value for diagnosis of pulmonary hypertension in MS patient. Echocardiography is an important non-invasive investigation for diagnosis, monitoring and selection of treatment and for prediction of mortality in MS patient. Obtaining good quality of 2D echocardiography is problematic in remote areas and they are not feasible for wide spread use due to cost and availability. So, ECG may be a guide for selecting appropriate patient for further testing.

**Objectives:** This study was planned to identify more accurate parameters of ECG for prediction of pulmonary hypertension and Right Ventricular Hypertrophy (RVH) in patients with mitral stenosis.

**Methodology:** This cross-sectional observational study was conducted in the Department of Cardiology, DMCH, from March 2018 to February 2019. A total of 100 patients with mitral stenosis (MS) who met the inclusion and exclusion criteria were enrolled. Detailed clinical history, physical examination, and baseline investigations were recorded for all participants. The study population was divided into two groups: Group I: MS patients without pulmonary hypertension (PASP < 35 mmHg). Group II: MS patients with pulmonary hypertension (PASP ≥ 35 mmHg). A 12-lead ECG and Doppler echocardiogram were performed within 24 hours of the patient's first contact. Fourteen different ECG parameters and criteria for right ventricular hypertrophy (RVH) were assessed. Statistical analysis was performed using SPSS version 22.0 for Windows.

**Results:** 14 patients were found in group I and 86 patients were found in group II. Among the Group-II patients 18 patients had mild pulmonary hypertension (PASP = 35 ≤ 50 mmHg), 47 patients had moderate pulmonary hypertension (PASP = 50 ≤ 70 mmHg) and 21 patients had severe pulmonary hypertension (PASP ≥ 70 mmHg). Average age of patient in group-I: was 38.71 ± 9.6 years and average age of patients in group-II was 43.8 ± 13.1 years (p = 0.16) Sex distribution was also identical between 2 groups (p = 0.92). This study showed that among the different ECG criteria for detection of RVH in mitral stenosis patients (Which is a surrogate marker for pulmonary hypertension), only a few had good predictive value. In mild pulmonary hypertension, only R in V1 ≥ 7 mm has sensitivity (66.7%), specificity (100%), PPV (100%) and NPV (37.5%). In moderate and severe pulmonary hypertension, R in V1 ≥ 7 mm, R/S in V1 > 1 and R

Submitted: March 07, 2025

Published: November 07, 2025

 10.24018/lejmed.2025.7.6.2302

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in V1+S in V5  $\geq 10$  mm had good sensitivity (60.5% and 63.2%; 65.1% and 68.4%; 53.5% and 63.2% respectively), good specificity (100% and 100%; 100% and 100%; 100% and 100% respectively), good PPV (100% and 100%; 100% and 100%; 100% and 100% respectively) and NPV (19% and 22.2%; 21.1% and 25%; 16.7% and 22.2% respectively).

**Conclusion:** The sensitivity of the ECG parameters was as a whole low to moderate in detection of pulmonary hypertension by assessing presence of RVH. However, certain ECG criteria for RVH detection in mitral stenosis patients have acceptable predictive value only in moderate to severe pulmonary hypertension.

**Keywords:** Electrocardiographic, Mitral Stenosis, Prediction, Pulmonary Hypertension.

## 1. INTRODUCTION

Mitral stenosis (MS) is the most common valvular heart disease worldwide. The majority of cases are caused by rheumatic heart disease (RHD), which remains prevalent in developing countries. Approximately 40% of patients with RHD have isolated MS; however, only 60% of these patients report a prior history of rheumatic fever [1]. Rheumatic MS is a progressive disease. In developing countries, the disease often progresses more rapidly, leading to symptoms by the age of 20—a condition referred to as juvenile MS—typically within five years of the initial episode of rheumatic fever. The mean age of symptom onset in these regions is between the third and fourth decade of life. Progression from mild to severe disability usually takes about a decade. Once symptoms develop, the prognosis is poor if the disease remains untreated, with an overall mortality rate of 70% over an average period of 11 years. Two-thirds of all patients with rheumatic MS are female, and MS shows a strong female preponderance with a 3:1 ratio [2]. Pulmonary hypertension (PH) is a major hemodynamic consequence and complication of MS. In patients with mild to moderate MS without elevated pulmonary vascular resistance, pulmonary arterial pressure may be normal or only slightly elevated at rest, but rises during exercise. In contrast, patients with severe MS or significantly increased pulmonary vascular resistance often have elevated pulmonary arterial pressure even at rest [3]. PH in MS leads to right ventricular pressure overload, right ventricular hypertrophy (RVH), and eventually right ventricular failure [4]. Early detection of PH in MS patients is therefore critical, both clinically and through investigations. In our country, rheumatic mitral stenosis is common [4]. Electrocardiography (ECG) can serve as a useful tool for predicting PH. A 12-lead ECG is easily accessible, inexpensive, and interpretation skills are typically included in basic medical training. Different diseases may have distinct ECG criteria for RVH. In MS, ECG patterns focusing on the R and S wave amplitudes and the R/S ratio in lead V1 have been found to be more predictive of PH than those focusing on leads V5 and V6. Specifically, evaluating the R and S amplitudes in V1 along with right axis deviation  $\geq 110^\circ$  has shown excellent predictive value for PH [5]. Understanding these ECG parameters is therefore important for clinicians managing MS patients. Echocardiography remains the primary imaging modality for assessing MS. However,

obtaining high-quality two-dimensional echocardiograms can be challenging in remote areas and is often costly. Additionally, the expertise required for performing and interpreting echocardiograms is not always readily accessible. Therefore, if validated, ECG may serve as a practical and cost-effective tool to guide clinicians in selecting patients for further echocardiographic evaluation, particularly for detecting significant PH. Several ECG criteria have been developed to identify RVH, though sensitivity and specificity vary widely. A novel ECG criterion, based on spatial changes in the QRS complex observed in vector cardiography, has demonstrated improved sensitivity and specificity for detecting RVH in MS patients. This criterion is simple, requires only linear measurements, and supplements the diagnostic capability of standard ECG and vector cardiogram-derived criteria [6]–[8]. Pulmonary hypertension is typically measured using Doppler echocardiography or cardiac catheterization. Measurement of right ventricular systolic pressure (RVSP) by transthoracic echocardiography (TTE) Doppler correlates well with values obtained through direct right-sided catheterization and provides an accurate and valid estimate of pulmonary systolic pressure in patients without pulmonary stenosis [9]–[15]. In this study, we aimed to identify ECG parameters with high sensitivity, specificity, and predictive value for diagnosing RVH and PH in patients with mitral stenosis.

## 2. METHODS & MATERIALS

This cross-sectional observational study was conducted in the Department of Cardiology, Dhaka Medical College Hospital, Dhaka, from March 2018 to February 2019. A total of 100 patients with mitral stenosis were included. Patients with a history of myocardial infarction, those with a pacemaker, poor-quality ECGs, left bundle branch block, or without measurable pulmonary artery systolic pressure (PASP) by transthoracic echocardiography (TTE) were excluded. Additional exclusion criteria included pulmonary stenosis, left ventricular dysfunction, chronic obstructive pulmonary disease (COPD), significant mitral or aortic regurgitation, congenital heart disease, and atrial fibrillation. Clinical history, physical examination, and baseline investigations were recorded for all participants. The study population was divided into two groups:

- **Group I:** MS patients without pulmonary hypertension (PASP < 35 mmHg), n = 14
- **Group II:** MS patients with pulmonary hypertension (PASP ≥ 35 mmHg), n = 86

Within Group II, 18 patients had mild pulmonary hypertension (PASP 35 ≤ 50 mmHg), 47 had moderate pulmonary hypertension (PASP 50 ≤ 70 mmHg), and 21 had severe pulmonary hypertension (PASP ≥ 70 mmHg). Transthoracic echocardiography was performed by trained personnel at the Dhaka Medical College Cardiac Centre. The 12-lead ECG was done by trained technicians and reviewed by two independent cardiologists. We studied the following ECG parameters of RVH as proposed by two main cardiology and ECG text books and different criteria of RVH: [5], [16]–[21].

ECG Criteria of RVH:

- R wave in lead I ≤ 2 mm;
- R wave in V1 ≥ 7 mm;
- S wave in V1 ≤ 2 mm;
- R/S in V1 ≥ 1;
- R wave in V5 ≤ 5 mm;
- R/S in V6 ≤ 1;
- R wave in V1 + S wave in V5 ≥ 10 mm;
- QRS axis > 90°;
- presence of qR in V1;
- R in aVR ≥ 11.5;
- presence of RBBB;
- S in V6 ≥ 7 mm;
- p ≥ 2.5 mm in lead II;
- R/S Ratio in lead I < 1;

All the patients having MS with or without pulmonary hypertension attending into Cardiology Department of Dhaka Medical College Hospital (DMCH) for investigation and / or treatment purpose, within the study period. Patients with MS with or without pulmonary hypertension fulfilling the inclusion and exclusion criteria were taken as sampling population by purposive sampling. Patients with MS who presented in the department of cardiology, (DMCH), through emergency or outpatient department were assessed first by attending doctor and then evaluated by the principal investigator. MS patients with or without pulmonary hypertension fulfilling the inclusion and exclusion criteria were taken as cases. Written informed consent was taken from all the study subjects. Detailed history, clinical examination and relevant investigation reports of all patients were recorded in pre-designed data collection sheet at the beginning of the study. Transthoracic echocardiography and ECG were performed within twenty-four hours of first contact.

**Statistical analysis:** Statistical analysis was conducted using SPSS 22.0 for windows software. Categorical data was expressed in frequencies and corresponding percentages. Parametric data was expressed in mean ± SD. Parametric data was evaluated by independent sample t test and categorical data was evaluated by Chi-square test as needed. Pearson correlation and correlation t test was observed between values when necessary. Level of significance for all analytical test was set at 0.05 and p-value ≤ 0.05 is considered significant. Written consent was received from each individual prior to inclusion in the study.

### 3. RESULTS

One hundred patients having MS with or without pulmonary hypertension who presented in the cardiology department within the study period who fulfilling inclusion and exclusion criteria were included in this study. The study population was divided into two groups. Group I: MS patients without pulmonary hypertension (PASP < 35 mmHg), (n = 14) patients, Group-II: MS Patients with pulmonary hypertension (PASP ≥ 35 mmHg), (n = 86). Among the Group-II patients 18 patients had mild pulmonary hypertension (PASP = 35 ≤ 50 mmHg), 47 patients had moderate pulmonary hypertension (PASP = 50 ≤ 70 mmHg) and 21 patients had severe pulmonary hypertension (PASP ≥ 70 mmHg). The general objective of the study was to assess efficacy of electrocardiographic findings for prediction of moderate to severe pulmonary hypertension in patients with mitral stenosis. Specific Objectives were to assess ECG parameters for the presence of RVH in all the study subjects, to assess the pulmonary arterial systolic pressure (PASP) in all MS patients by transthoracic echocardiography, to compare different ECG parameters of RVH with echocardiography findings of different degree of pulmonary hypertension in mitral stenosis patients, to find out the sensitivity, specificity, positive and negative predictive values of these parameters to predict pulmonary hypertension by detecting RVH in mitral stenosis patients. Appropriate statistical techniques were applied where necessary and the findings are documented below:

**Table I** shows the comparison of demographic characteristics between MS patients with Pulmonary Hypertension and without Pulmonary Hypertension (HTN).

The electrocardiographic findings were shown in **Table II**. RVH were significantly higher in group II patients than group I.

The above **Table III** shows the distribution of different ECG patterns suggestive of right ventricular hypertrophy (RVH) among the study population.

The **Table IV** shows the distribution of different ECG patterns suggestive of right ventricular hypertrophy (RVH) among the study population. The **Table IV** also describes the performance of the above-mentioned ECG characteristics between the study patients.

The **Table V** shows the accuracy of different ECG patterns in predicting RVH. PPVs (true hypertrophy out of predictive hypertrophy) of almost all the ECG parameters are well appreciable (around 90%). The PPVs of R wave in lead I ≤ 2 mm, R/S in V6 ≤ 1 mm and p ≥ 2.5 in lead I, R/S in I < 1 even reached to 100%.

The **Table VI** shows that the ECG parameters are not efficacious in predicting RVH in patients of mitral stenosis with mild pulmonary hypertension except R wave in V1 > 7 mm.

The prevalence, accuracy and predictive values of ECG patterns suggestive of RVH in 47 patients with moderate pulmonary hypertension (PASP 50 ≤ 70 mm) were shown in the **Table VII** and **Fig. 1**.

The prevalence, accuracy and predictive values of ECG patterns suggestive of RVH in 21 patients with severe

TABLE I: COMPARISON OF DEMOGRAPHIC CHARACTERISTICS OF THE STUDY POPULATION (N = 100)

| Demographic characteristics | Group I (n = 14) |      | Group II (n = 86) |      | p-Value |
|-----------------------------|------------------|------|-------------------|------|---------|
|                             | Number           | %    | Number            | %    |         |
| Age (yrs)                   |                  |      |                   |      |         |
| ≤ 30                        | 4                | 28.6 | 17                | 19.8 |         |
| 31–40                       | 4                | 28.6 | 24                | 27.9 |         |
| 41–50                       | 5                | 35.7 | 21                | 24.4 |         |
| 51–60                       | 1                | 7.1  | 16                | 18.6 |         |
| > 60                        | 0                | 0.0  | 8                 | 9.3  |         |
| Mean ± SD                   | 38.7 ± 9.6       |      | 43.8 ± 13.1       |      | 0.16*   |
| Gender                      |                  |      |                   |      |         |
| Male                        | 4                | 28.6 | 27                | 31.4 | 0.92*   |
| Female                      | 10               | 71.4 | 59                | 68.6 |         |

Note: Group I = MS without pulmonary hypertension.

Group II = MS with pulmonary hypertension.

Chi Square test for qualitative data and unpaired t-test for quantitative data was applied.

\* Means not significant ( $p > 0.05$ ).

TABLE II: ELECTROCARDIOGRAPHIC FINDINGS OF THE STUDY POPULATION (N = 100)

| ECG Findings | Total (n = 100) | Group-I (n = 14) | Group-II (n = 86) | p-Value |
|--------------|-----------------|------------------|-------------------|---------|
| Normal ECG   | 15              | 6 (42.8%)        | 9 (10.5%)         | 0.001** |
| RVH          | 85              | 8 (57.2%)        | 77 (89.5%)        |         |

Note: \*\*means significant ( $p < 0.05$ ).

TABLE III: PREVALENCE OF ECG PATTERNS OF RVH OF THE STUDY POPULATION (N = 100)

| ECG patterns                        | Group-I (MS with pulmonary hypertension) (n = 14) |      | (Group-II (MS without pulmonary hypertension) (n = 86) |      | p-Value |
|-------------------------------------|---------------------------------------------------|------|--------------------------------------------------------|------|---------|
|                                     | Number                                            | %    | Number                                                 | %    |         |
| R wave in V1 ≥ 7 mm                 | 4                                                 | 28.6 | 51                                                     | 59.3 | 0.03**  |
| R/S in V1 > 1                       | 2                                                 | 14.3 | 49                                                     | 57.0 | 0.004** |
| R wave in V1 + S wave in V5 ≥ 10 mm | 1                                                 | 7.1  | 41                                                     | 47.7 | 0.007** |
| S wave in V1 ≤ 2 mm                 | 1                                                 | 7.1  | 42                                                     | 48.8 | 0.003** |
| QRS axis > 90°                      | 2                                                 | 14.3 | 41                                                     | 47.7 | 0.02**  |
| R wave in lead I ≤ 2 mm             | 0                                                 | 0.0  | 36                                                     | 41.9 | 0.002** |
| P ≥ 2.5 in lead II                  | 0                                                 | 0.0  | 30                                                     | 34.9 | 0.009** |
| qR in V1                            | 1                                                 | 7.1  | 24                                                     | 27.9 | 0.09*   |
| R wave in V5 ≤ 5 mm                 | 1                                                 | 7.1  | 17                                                     | 19.8 | 0.25*   |
| R/S in V6 ≤ 1 mm                    | 0                                                 | 0.0  | 14                                                     | 16.3 | 0.21*   |
| R/S in I < 1                        | 0                                                 | 0.0  | 20                                                     | 23.3 | 0.04**  |
| RBBB                                | 2                                                 | 14.3 | 18                                                     | 20.9 | 0.56*   |
| S in V6 ≥ 7 mm                      | 1                                                 | 7.1  | 19                                                     | 22.1 | 0.19*   |

Note: \*\*means significant ( $p < 0.05$ ), \*means not significant ( $p > 0.05$ ).

p-value reached from Chi Square and Fisher's Exact test for qualitative data.

pulmonary hypertension (PASP > 70 mm) were shown in the [Table VIII](#) and [Fig. 2](#).

#### 4. DISCUSSION

In our study, 100 patients of mitral stenosis were chosen for observation. The study population was divided into two groups. Group I: MS patients without pulmonary hypertension (PASP < 35 mmHg), (n = 14) patients, Group-II: MS Patients with pulmonary hypertension (PASP ≥ 35 mmHg), (n = 86). Among the Group-II patents 18 patients had mild pulmonary hypertension (PASP = 35 ≤ 50 mmHg), 47 patients had moderate pulmonary hypertension (PASP = 50 ≤ 70 mmHg) and

21 patients had severe pulmonary hypertension (PASP ≥ 70 mmHg). The general objective of the study was to assess efficacy of electrocardiographic findings for prediction of moderate to severe pulmonary hypertension in patients with mitral stenosis. Specific Objectives were to assess ECG parameters for the presence of RVH in all the study subjects, to assess the pulmonary arterial systolic pressure (PASP) in all MS patients by transthoracic echocardiography, to compare different ECG parameters of RVH with echocardiography findings of different degree of pulmonary hypertension in mitral stenosis patients, to find out the sensitivity, specificity, positive and negative predictive values of these parameters to predict pulmonary hypertension by detecting RVH in mitral stenosis patients.

TABLE IV: PREVALENCE AND PREDICTIVE VALUE OF ECG PATTERNS OF RVH OF THE STUDY POPULATION (N = 100)

| ECG patterns                             | Group I (n = 14) |      | Group II (n = 86) |      | Prevalence % | TN No. | FP No. | TP No. | FN No. | Sen % | Spe % | PPV % | NPV % | p-Value |
|------------------------------------------|------------------|------|-------------------|------|--------------|--------|--------|--------|--------|-------|-------|-------|-------|---------|
|                                          | No.              | %    | No.               | %    |              |        |        |        |        |       |       |       |       |         |
| R wave in V1 $\geq 7$ mm                 | 4                | 28.6 | 51                | 59.3 | 55.0         | 10     | 4      | 51     | 35     | 59.3  | 71.4  | 92.7  | 22.2  | 0.03**  |
| R/S in V1 $> 1$                          | 2                | 14.3 | 49                | 57.0 | 51.0         | 12     | 2      | 49     | 37     | 57.0  | 85.7  | 96.1  | 24.5  | 0.004** |
| R wave in V1 + S wave in V5 $\geq 10$ mm | 1                | 7.1  | 45                | 52.3 | 46.0         | 13     | 1      | 45     | 41     | 52.3  | 92.9  | 97.8  | 24.1  | 0.001** |
| S wave in V1 $\leq 2$ mm                 | 1                | 7.1  | 42                | 48.8 | 43.0         | 13     | 1      | 42     | 44     | 48.8  | 92.9  | 97.7  | 22.8  | 0.003** |
| QRS axis $> 90^\circ$                    | 2                | 14.3 | 41                | 47.7 | 43.0         | 12     | 2      | 41     | 45     | 47.7  | 85.7  | 95.3  | 21.2  | 0.02**  |
| R wave in lead I $\leq 2$ mm             | 0                | 0.0  | 36                | 41.9 | 36.0         | 14     | 0      | 36     | 50     | 41.9  | 100.0 | 100.0 | 21.9  | 0.002** |
| p $\geq 2.5$ in lead II                  | 0                | 0.0  | 30                | 34.9 | 30.0         | 14     | 0      | 30     | 56     | 34.9  | 100.0 | 100.0 | 20.0  | 0.009** |
| qR in V1                                 | 1                | 7.1  | 24                | 27.9 | 25.0         | 13     | 1      | 24     | 62     | 27.9  | 92.9  | 96.0  | 17.3  | 0.09*   |
| R/S in I $< 1$                           | 0                | 0.0  | 20                | 23.3 | 20.0         | 14     | 0      | 20     | 66     | 23.3  | 100.0 | 100.0 | 17.5  | 0.04**  |
| RBBB                                     | 2                | 14.3 | 18                | 20.9 | 20.0         | 12     | 2      | 18     | 68     | 20.9  | 85.7  | 90.0  | 15.0  | 0.56*   |
| S in V6 $\geq 7$ mm                      | 1                | 7.1  | 19                | 22.1 | 20.0         | 13     | 1      | 19     | 67     | 22.1  | 92.9  | 95.0  | 16.2  | 0.19*   |
| R wave in V5 $\leq 5$ mm                 | 1                | 7.1  | 17                | 19.8 | 18.0         | 13     | 1      | 17     | 69     | 19.8  | 92.9  | 94.4  | 15.9  | 0.25*   |
| R/S in V6 $\leq 1$ mm                    | 0                | 0.0  | 14                | 16.3 | 14.0         | 14     | 0      | 14     | 72     | 16.3  | 100.0 | 100.0 | 16.3  | 0.21*   |

Note: TP = True positive, FP = False positive, FN = False negative, TN = True negative, Sen = Sensitivity, Spe = Specificity, PPV = Positive Predictive Value, NPV = Negative predictive value.

TABLE V: ACCURACY OF DIFFERENT ECG PATTERNS IN PREDICTING RVH IN MITRAL STENOSIS PATIENTS WITH PULMONARY HYPERTENSION (N = 86)

| Characteristics                          | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) | p-Value |
|------------------------------------------|-----------------|-----------------|---------|---------|---------|
| R wave in V1 $\geq 7$ mm                 | 59.3            | 71.4            | 92.7    | 22.2    | 0.03**  |
| R/S in V1 $> 1$                          | 57.0            | 85.7            | 96.1    | 24.5    | 0.004** |
| R wave in V1 + S wave in V5 $\geq 10$ mm | 47.7            | 92.3            | 97.6    | 22.4    | 0.007** |
| S wave in V1 $\leq 2$ mm                 | 48.8            | 92.9            | 97.7    | 22.8    | 0.003** |
| QRS axis $> 90^\circ$                    | 47.7            | 85.7            | 95.3    | 21.1    | 0.02**  |
| R wave in lead I $\leq 2$ mm             | 41.9            | 100.0           | 100.0   | 21.9    | 0.002** |
| p $\geq 2.5$ in lead II                  | 34.9            | 100.0           | 100.0   | 20.0    | 0.009** |
| qR in V1                                 | 27.9            | 92.9            | 96.0    | 17.3    | 0.09*   |
| R/S in I $< 1$                           | 23.3            | 100.0           | 100.0   | 17.5    | 0.04**  |
| RBBB                                     | 20.9            | 85.7            | 90.0    | 15.0    | 0.73*   |
| S in V6 $\geq 7$ mm                      | 22.1            | 92.9            | 95.0    | 16.2    | 0.29*   |
| R wave in V5 $\leq 5$ mm                 | 19.8            | 92.9            | 94.4    | 15.9    | 0.45*   |
| R/S in V6 $\leq 1$ mm                    | 16.3            | 100.0           | 100.0   | 16.3    | 0.21*   |

In our study, among the study population there was no significant difference between mean ages of the two groups of patients. Average age of patient in group-I: was  $38.71 \pm 9.6$  years and average age of patients in group-II was  $43.8 \pm 13.1$  years ( $p = 0.16$ ). Sex distribution was also identical between 2 groups ( $p = 0.92$ ). In our study, we found among 100 patients of mitral stenosis, Normal ECG = 15%, RVH = 85%. RVH was significant more in group II patients (89.5%), ( $p = 0.001$ ). In this study 14 different ECG criteria of RVH were tested for detection of pulmonary hypertension in mitral stenosis patients. Among the tested ECG parameters in group-II ( $n = 86$ , PASP  $> 35$  mmHg), Prevalence of R/S in V1 (51%), R wave in V1  $\geq 7$  mm

(55%), R wave in V1 + S wave V5  $\geq 10$  (46%), QRS axis  $> 90^\circ$  (43%), S in V1  $\leq 2$  mm (43%), R wave in lead I  $\leq 2$  mm (36%). Among these parameters, R wave in V1 has the highest prevalence (55%). The overall prevalence of ECG parameters in group-II patients ranges from 14% to 55%. According to Al-Naamani *et al.*, [5] among the tested ECG parameters, prevalence of R in V5  $\leq 5$  mm (13.5%), QRS axis  $\geq 90^\circ$  (8.1%), R in lead I  $\leq 2$  mm (8%), R/S in V1  $\geq 1$  (7.1%), qR in V1 (6.3%). Among these parameters, R in V5  $\leq 5$  mm has the highest prevalence. The overall prevalence ranges from 6.3% to 13.5%. According to Butler *et al.*, [6] among the tested ECG parameters, prevalence of R in V1 + S in V5  $\geq 10$  mm (44%), R in V1  $\geq 7$  mm (30%), R/S

TABLE VI: PREVALENCE, ACCURACY AND PREDICTIVE VALUES OF ECG PATTERNS SUGGESTIVE OF RVH IN MITRAL STENOSIS PATIENTS WITH MILD PULMONARY HYPERTENSION (N = 18)

| ECG patterns                             | Prevalence n (%) | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) | p-Value |
|------------------------------------------|------------------|-----------------|-----------------|---------|---------|---------|
| R wave in V1 $\geq$ 7 mm                 | 10 (55.6)        | 66.7            | 100.0           | 100.0   | 37.5    | 0.03**  |
| S wave in V1 $\leq$ 2 mm                 | 8 (44.4)         | 53.3            | 100.0           | 100.0   | 30.0    | 0.09*   |
| R wave in V1 + S wave in V5 $\geq$ 10 mm | 8 (44.4)         | 53.3            | 100.0           | 100.0   | 30.0    | 0.09*   |
| R wave in lead I $\leq$ 2 mm             | 7 (38.9)         | 40.0            | 66.7            | 85.7    | 18.2    | 0.82*   |
| R/S in V1 $>$ 1                          | 6 (33.3)         | 40.0            | 100.0           | 100.0   | 25.0    | 0.18*   |
| R wave in V5 $\leq$ 5 mm                 | 5 (27.8)         | 33.3            | 100.0           | 100.0   | 23.1    | 0.24*   |
| QRS axis $>$ 90°                         | 5 (27.8)         | 26.7            | 66.7            | 80.0    | 15.4    | 0.81*   |
| RBBB                                     | 5 (27.8)         | 26.7            | 80.0            | 66.7    | 15.4    | 0.81*   |
| p $\geq$ 2.5 in lead II                  | 4 (22.2)         | 26.7            | 100.0           | 100.0   | 21.4    | 0.31*   |
| R/S in I $<$ 1                           | 3 (16.7)         | 20.0            | 100.0           | 100.0   | 20.0    | 0.39*   |
| qR in V1                                 | 2 (11.1)         | 13.3            | 100.0           | 100.0   | 18.8    | 0.50*   |
| S in V6 $\geq$ 7 mm                      | 2 (11.1)         | 13.3            | 100.0           | 100.0   | 18.8    | 0.50*   |
| R/S in V6 $\leq$ 1 mm                    | 1 (5.6)          | 6.7             | 100.0           | 100.0   | 17.6    | 0.64*   |

TABLE VII: PREVALENCE, ACCURACY AND PREDICTIVE VALUES OF ECG PATTERNS SUGGESTIVE OF RVH IN MITRAL STENOSIS PATIENTS WITH MODERATE PULMONARY HYPERTENSION (N = 47)

| ECG patterns                             | Prevalence N (%) | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) | p-Value |
|------------------------------------------|------------------|-----------------|-----------------|---------|---------|---------|
| R/S in V1 $>$ 1                          | 28 (59.6)        | 65.1            | 100.0           | 100.0   | 21.1    | 0.01**  |
| R wave in V1 $\geq$ 7mm                  | 26 (55.3)        | 60.5            | 100.0           | 100.0   | 19.0    | 0.02**  |
| R wave in V1 + S wave in V5 $\geq$ 10 mm | 23 (48.9)        | 53.5            | 100.0           | 100.0   | 16.7    | 0.03**  |
| QRS axis $>$ 90°                         | 23 (48.9)        | 51.2            | 75.0            | 95.7    | 12.5    | 0.32*   |
| qR in V1                                 | 9 (19.1)         | 20.9            | 100.0           | 100.0   | 10.5    | 0.31*   |
| R wave in lead I $\leq$ 2 mm             | 21 (44.7)        | 46.5            | 75.0            | 95.2    | 11.5    | 0.41*   |
| S wave in V1 $\leq$ 2 mm                 | 21 (44.7)        | 46.5            | 75.0            | 95.2    | 11.5    | 0.41*   |
| p $\geq$ 2.5 in lead II                  | 16 (34.0)        | 37.2            | 100.0           | 100.0   | 12.9    | 0.13*   |
| S in V6 $\geq$ 7 mm                      | 13 (27.7)        | 30.2            | 100.0           | 100.0   | 11.8    | 0.20*   |
| RBBB                                     | 11 (23.4)        | 23.3            | 75.0            | 90.9    | 8.3     | 0.93*   |
| R wave in V5 $\leq$ 5 mm                 | 10 (21.3)        | 23.3            | 100.0           | 100.0   | 10.8    | 0.27*   |
| R/S in V6 $\leq$ 1 mm                    | 7 (14.9)         | 16.3            | 100.0           | 100.0   | 10.2    | 0.38*   |
| R/S in I $<$ 1                           | 7 (14.9)         | 16.3            | 100.0           | 100.0   | 10.0    | 0.38*   |

in  $v_1 \geq 1$  (28%), S1 S2 S3 (44%), S in V1  $\leq$  2 mm (22%), S in V6  $\geq$  3 mm (34%), Among these parameters, R in  $v_1 + S$  in  $v_5 \geq 10$ mm, has the highest prevalence (44%). The overall prevalence ranges from 22.2% to 44%. According to Boson *et al.*, [22]. Prevalence of tall R in II (32%), QRS axis  $\geq 90^\circ$  (23%), RBBB (10%), other parameters of RVH (41%). The overall prevalence ranges from 10% to 32%. Hiroki *et al.*, [19] found prevalence of tall R in V1 (55.8%), S in V 6 (15%), S in V1 (35%), QRS axis  $\geq 90^\circ$  (20%) Among these parameters, tall R in V1 has the highest prevalence. The overall prevalence ranges from 15% to 55.8%. So, result of our study mostly consists with the results of Butler *et al.*, [6] and Hiroki *et al.*, [19]. In our study, in group-II patients (n = 86), sensitivity of ECG parameters ranges from 16.3% to 59.3% and specificity ranges from 71.4% to 100% which is consistent with the findings of Algea *et al.* [23], where among the tested ECG parameters the sensitivity and specificity of RAD  $> 110^\circ$ ,

S in V5 or V6  $\geq 7$  mm and incomplete RBBB were 25% and 94%, 25% and 75%, 15% and 94% respectively. The sensitivity and specificity of group II patients also consist with Henken [24]. Where sensitivity ranges from 13% to 84% and specificity ranges from 70% to 100% and also consist with Murphy [25]. where sensitivity ranges from 57% to 66% and specificity ranges from 85% to 93%. The following ECG patterns had superior positive predictive values for pulmonary hypertension in group-II patients (PPV around 90%): R in lead I  $\leq 2$  mm, P  $\geq 2.5$  in lead II, R wave in V1+ S in V5  $\geq 10$  mm, R wave in V1  $\geq 7$  mm, S wave in V1  $\leq 2$  mm, R/S in V1  $> 1$ , QRS axis  $> 90^\circ$ , R/S ratio in lead I  $< 1$ . The PPVS of R wave in lead I  $\leq 2$  mm, R/S in V6  $\leq 1$  mm and P  $\geq 2.5$  mm in lead II, R/S ratio in lead I even reached to 100%. In diagnosing mild pulmonary hypertension (n = 18, PASP = 35 to  $< 50$  mmHg) in our study, R in V1  $\geq 7$  mm showed sensitivity (66.7%), specificity (100%), PPV (100%)

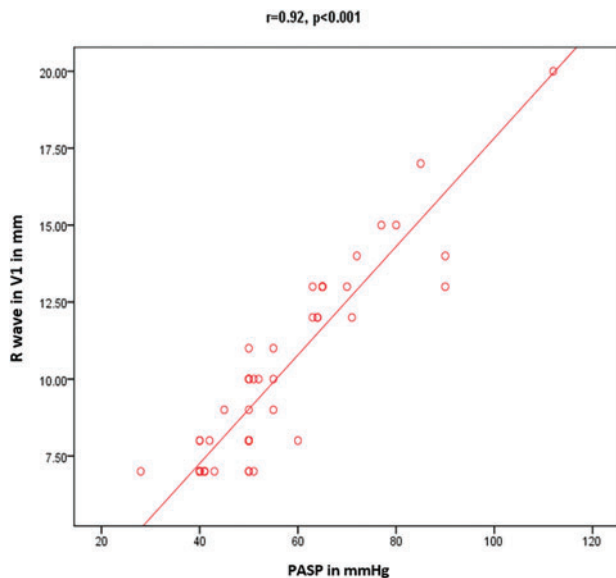


Fig. 1. Scatter plot diagram showing correlation between PASP and R wave in V1 among the study population.

and NPV (37.5%) Only this parameter was efficacious in detection of RVH in mild pulmonary hypertension and was statistically significant ( $p = 0.03$ ). In diagnosing moderate pulmonary hypertension ( $n = 47$ , PASP = 50 to < 70 mmHg), R in V1  $\geq 7$  mm, R/S in V1  $> 1$ , R in V1 + S in V5  $\geq 10$ , showed good sensitivity (60.5%, 65.1% and 53.5% respectively), good specificity (100% each), good PPV (100% each) and NPV (19%, 21.1%, 16.7% respectively). These 3 parameters were efficacious in predicting RVH in patients of mitral stenosis with moderate pulmonary hypertension and were statistically significant ( $p < 0.05$ ). In detecting severe pulmonary hypertension ( $n = 21$ , PASP  $> 70$  mmHg) the ECG parameters like: R wave in V1  $\geq 7$  mm, R wave in lead I  $\leq 2$  mm, R/S in V1  $\geq 1$ , R wave in V1 + S wave in V5  $\geq 10$  mm, QRS  $\geq 90^\circ$ , qR in V1,  $p \geq 2.5$  in II, R/S in I  $\leq 1$  demonstrated sensitivity and specificity of 63.2% and 100%, 42.1% and 100%, 68.4%

and 100%, 63.2% and 100%, 63.2% and 50%, 63.2% and 50%, 47.4% and 90%, 47.7% and 90% respectively. R/S in V1  $\geq 1$ , S wave in V1  $\leq 2$  mm. R/S in V1 and R wave in V1  $> 7$  mm had highest prevalence of 71.4% each. R/S in V1 beared highest sensitivity (68.4%). R wave in V1  $\geq 7$  mm, R wave in I  $\leq 2$  mm, R/S in V1  $\geq 1$ , R wave in V1 + S wave in V5  $\geq 10$  mm, RBBB, R/S in V6  $\leq 1$  mm had the highest PPV (100%) and highest specificity (100%). Among the tested ECG parameters in severe pulmonary hypertension, R in V1  $> 7$  mm, R/S in V1  $> 1$  and R in V1 + S in V5  $> 10$  mm had good sensitivity (63.2%; 68.4% and 63.2% respectively), good specificity (100% each), good PPV (100% each) and NPV (19% and 22.2%; 21.1% and 25%; 16.7% and 22.2% respectively). These 3 parameters were efficacious in predicting RVH in patients of mitral stenosis with severe pulmonary hypertension and were statistically significant ( $p < 0.05$ ) but according to Al-Naamani *et al.*, [5] only QRS axis  $> 110^\circ$  had superior PPV (73%). In this study we have observed there is a quantitative correlation between Tall R in V1 and PASP ( $r = 0.92$ ,  $p < 0.001$ ) and R wave V1 + S in V5  $\geq 10$  and PASP ( $r = 0.73$ ,  $p < 0.001$ ). According to Al-Naamani *et al.* [5], positive predictive values (PPV) and negative predictive values (NPV) of RV1  $\geq 7$  mm, RV5  $\leq 5$ , R in lead I  $\leq 2$  mm, S V1  $\leq 2$  mm, R/S in V1  $\leq 1$ , R/S V6  $\leq 1$ , RV1 + SV5  $\geq 10$  mm, QRS axis  $> 90^\circ$ , qR in V1,  $P > 2.5$  in lead II were 72.7% and 24.5%; 30.8% and 26.3; 81.5%; and 25.1%; 100% and 25.4%, 72.7% and 35.8%; 80.0% and 24.8%; 71.4% and 24.4; 94.7% and 25.6%; 0.0% and 23.9% respectively. The overall PPV ranges from 0.0% to 100%. S in V1  $\leq 2$  mm had the highest PPV (100%). But in our study the positive and negative predictive values of ECG parameters were much higher. This could be due to the fact that majority of population of Al-Naamani's study [5], had COPD and pulmonary hyperinflation which might have impeded the transmission of the right ventricular electrical forces.

TABLE VIII: PREVALENCE, ACCURACY AND PREDICTIVE VALUES OF ECG PATTERNS SUGGESTIVE OF RVH IN MITRAL STENOSIS PATIENTS WITH SEVERE PULMONARY HYPERTENSION (N = 21)

| ECG patterns                             | Prevalence n (%) | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) | p-Value |
|------------------------------------------|------------------|-----------------|-----------------|---------|---------|---------|
| R wave in V1 $\geq 7$ mm                 | 15 (71.4)        | 63.2            | 100.0           | 100.0   | 22.2    | 0.01**  |
| R/S in V1 $> 1$                          | 15 (71.4)        | 68.4            | 100.0           | 100.0   | 25.0    | 0.02**  |
| R wave in V1 + S wave in V5 $\geq 10$ mm | 14 (66.7)        | 63.2            | 100.0           | 100.0   | 22.2    | 0.03**  |
| S wave in V1 $\leq 2$ mm                 | 13 (61.9)        | 57.9            | 0.0             | 84.6    | 0.0     | 0.24*   |
| QRS axis $> 90^\circ$                    | 13 (61.9)        | 63.2            | 50.0            | 92.3    | 12.5    | 0.71*   |
| qR in V1                                 | 13 (61.9)        | 63.2            | 50.0            | 92.3    | 12.5    | 0.71*   |
| $P \geq 2.5$ in lead II                  | 10 (47.6)        | 47.4            | 90.0            | 50.0    | 9.1     | 0.94*   |
| R/S in I $< 1$                           | 10 (47.6)        | 47.7            | 90.0            | 50.0    | 9.1     | 0.94*   |
| R wave in lead I $\leq 2$ mm             | 8 (38.1)         | 42.1            | 100.0           | 100.0   | 15.4    | 0.24*   |
| R/S in V6 $\leq 1$ mm                    | 6 (28.6)         | 31.6            | 100.0           | 100.0   | 13.3    | 0.35*   |
| S in V6 $\geq 7$ mm                      | 4 (19.0)         | 21.2            | 100.0           | 100.0   | 11.8    | 0.47*   |
| R wave in V5 $\leq 5$ mm                 | 2 (9.5)          | 10.5            | 100.0           | 100.0   | 10.5    | 0.63*   |
| RBBB                                     | 2 (9.5)          | 10.5            | 100.0           | 100.0   | 10.5    | 0.63*   |

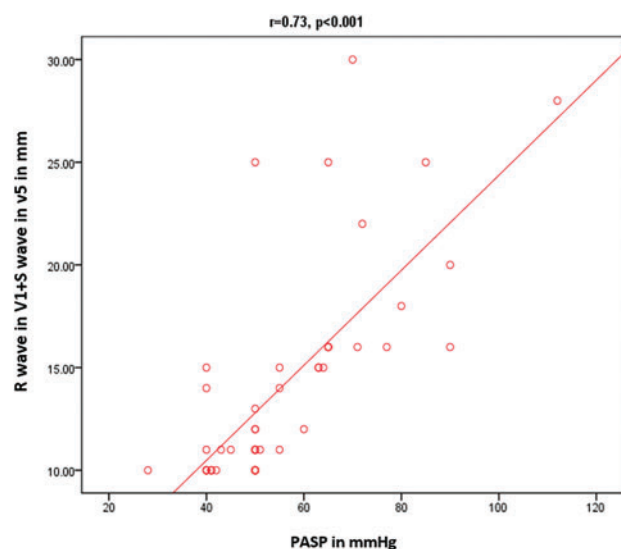


Fig. 2. Scatter plot diagram showing correlation between PASP and R wave in V1 + S wave in V5 among the study population.

## 5. CONCLUSION

The present study demonstrates that careful evaluation of the electrocardiogram (ECG) can provide valuable information regarding the hemodynamic status of patients with mitral stenosis, particularly the presence of pulmonary hypertension. In our study, ECG proved to be a significant tool for diagnosing right ventricular hypertrophy (RVH); however, constitutional factors, such as chest wall thickness, may influence its accuracy. ECG patterns focusing on the R and S wave amplitudes and the R/S ratio in lead V1 were more predictive than those involving leads V5 and V6. Among various ECG criteria for detecting RVH—a surrogate marker for pulmonary hypertension—only a few showed good predictive value. **Mild pulmonary hypertension:** R in V1 > 7 mm showed a sensitivity of 66.7%, specificity of 100%, positive predictive value (PPV) of 100%, and negative predictive value (NPV) of 37.5%. **Moderate and severe pulmonary hypertension:** R in V1 > 7 mm, R/S in V1 > 1, and R in V1 + S in V5 > 10 mm demonstrated good sensitivity (60.5% & 63.2%; 65.1% & 68.4%; 53.5% & 63.2%, respectively), specificity (100% for all), PPV (100% for all), and moderate NPV (ranging 16.7%–25%). Additionally, a significant positive linear relationship was observed between R in V1 ≥ 7 mm and pulmonary artery systolic pressure (PASP), as well as R in V1 + S in V5 ≥ 10 mm and PASP. Therefore, the presence of any of these ECG parameters should prompt further diagnostic evaluation for a more detailed assessment of cardiac function and PASP.

## CONFLICT OF INTEREST

The authors declare that they do not have any conflict of interest.

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