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Echocardiographic correlation of right ventricular dysfunction in right ventricular myocardial infarction with inferior wall myocardial infarction

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Abstract
Context
In view of the right ventricular (RV) volume pump traits, right ventricular injury (RVI) with hemodynamic compromise needs a specific treatment [1]. RVI in ST-elevation myocardial infarction (STEMI) can cause intense hemodynamic derangements and is associated with increased mortality and morbidity [2]. The primary cause of death in sufferers with acute right ventricular myocardial Infarction (RVMI) is cardiogenic shock [3]. Therefore, early and accurate diagnosis is essential for optimizing treatment strategies.
In medical practice, echocardiography provides major tool for evaluation of RV structure and function. In comparison to other modalities, it provides added advantages of versatility and easy availability.
Aims
- To evaluate and compare Echocardiographic Methodologies in Inferior Wall Myocardial Infarction with Right Ventricular Myocardial Infarction and it's dysfunction assessment with it's prognostic implication in assessing the risk of mortality in different sub groups.

Setting and Design: This study was performed in the Department of General Medicine, Mata Gujri Memorial Medical College and Lions Sewa Kendra Hospital, Kishanganj, Bihar for 100 consecutive patients admitted with IWMI during the period of March 2022 – December 2022, for a period of 10 months. The study is a prospective observational study.
Material and methods: Group 1 – Patients with IWMI with RVMI on ECG (n = 47)
Group 2 – Patients with IWMI without RVMI on ECG (n = 53) within 48 hours of onset of symptoms and within 24 hours whenever feasible, Transthoracic echocardiography performed in all patients.
Statistical analysis used: Comparison of measurements between Group 1 and group 2 was performed using a two tailed Student's *t*-test.
Results
- The end-diastolic diameter of RV was increased in patients with RVMI. In half of the patients with right ventricular involvement, Tricuspid Regurgitation was noted which was mild in majority of cases.
- There was a significant statistical decrease noted in Tricuspid Annular Plane Systolic Excursion (TAPSE) in patients with right ventricular myocardial infarction. Nearly two-fold rise in Myocardial Performance Index (MPI) was noted as compared to the reference values in patients with RVMI.

Conclusions: The dimensions and contractility of right ventricle were considered insignificant in detecting RVMI. Raised MPI values were associated with higher mortality. RV functional abnormality was worse in patients whose echo was done within 24 hrs. The systolic velocity of Right Ventricle in RVMI patients was less in comparison to patients without RVMI.

Keywords: RVMI- right ventricular myocardial infarction, MPI – myocardial performance index, TDI – tissue doppler imaging, TAPSE - tricuspid annular peak systolic excursion, Sm – Myocardial systolic velocity, Em – early phase of diastolic myocardial velocity, Am – late phase of diastolic myocardial velocity

Introduction

In view of the right ventricular (RV) volume pump traits, right ventricular injury (RVI) with hemodynamic compromise needs a specific treatment [1]. RVI in ST-elevation myocardial infarction (STEMI) can cause intense hemodynamic derangements and is associated with increased mortality and morbidity [2]. The primary cause of death in sufferers with acute right ventricular myocardial Infarction (RVMI) is cardiogenic shock [3]. Therefore, early and accurate diagnosis is essential for optimizing treatment strategies.
For this reason, acute RVMI complicating inferior wall myocardial infarction (IMI) has worse prognosis. It is an independent predictor of primary complications and mortality [4, 5].
Establishing the presence of RVMI in living patients is difficult because right ventricular dysfunction and stunning frequently is of a transient nature.
Complex Anatomy of Right Ventricle makes it difficult to assess its functionality. Problem is faced as a consequence of irregularities in the ventricular cavities and abnormalities in wall motion in patients.
The Geometric and functional assumptions to assess Left Ventricular (LV) function does not hold true for Right Ventricular (RV) Function. The complex shape of the RV makes quantification difficult [6].

Diagnosis of RVMI by electrocardiography

The standard 12-lead electrocardiogram (ECG) provides information on the left ventricle but yields limited information on the right side of the heart. Leads V_1 and V_2 on the standard ECG provide only a partial view of the right ventricle free wall. The ECG findings suggestive of RVMI on the standard 12-lead ECG include ST elevation in leads II, III, and aVF with reciprocal ST depression in the lateral leads. Characteristically in RVMI, the ST elevation in lead III is greater than in lead II, and the ST elevation in lead aVF is greater than the ST depression in lead V_2 [7].

Right-sided precordial leads are critical to the evaluation of suspected RVMI. Using right-sided precordial leads, ST-segment elevation in lead $V_4R \geq 1.0$ mm is diagnostic of RVMIST-segment elevation in right-sided precordial leads, especially in V_4R, correlates with reduced right ventricle ejection fraction and is associated with major complications and inhospital mortality [8-10].

Various non-invasive assessment of right ventricular function

a. ***Echocardiography***
b. ***Radionuclide angiography***
c. ***Cardiac computed tomography***
d. ***Cardiac magnetic resonance***
e. ***Invasive assessment of right ventricular function***

Each of these has its own limitations and is expensive and availability is limited. Echocardiography provides a readily accessible tool for the evaluation of right ventricular function.

Aim of the Study

- To evaluate and compare various echocardiographic methodologies in assessing Right Ventricular function in the setting of Inferior wall myocardial infarction.
- To assess patients without RVMI on ECG but with echocardiographic findings of RV dysfunction.
- To compare echocardiography findings in RV function with echocardiography done at different time intervals after the onset of myocardial infarction.
- To compare RV dysfunction in patients who are thrombolysed & those not thrombolysed.
- To assess the clinical parameters and echocardiographic findings associated with increased mortality.
- To compare RV dysfunction in males & females and in different age groups.

Material and Methods

The study was performed in the Department of Medicine, Mata Gujri Memorial Medical College & LSK Hospital, Kishanganj for 100 consecutive patients admitted with IWMI during the period of March 2022 – December 2022, for a period of 10 months. The study is a prospective observational study involving 100 patients.

Study Group Selection

Ethical committee clearance was obtained to conduct the study in our hospital.

All subjects provided written informed consent to participate in the study before inclusion.

Inclusion Criteria

1. IWMI with and without RVMI on ECG.
2. First MI (MI diagnosed by history, ECG & enzymes).
3. Within 48 hours of onset of chest pain.
4. Any age-group
5. Both sexes
6. Both thrombolysed & not thrombolysed patients.

Exclusion Criteria

1. COPD/PPH/Cor pulmonale
2. Valvular HD/Congenital HD.
3. Previous MI.
4. Complete heart block, Arrhythmias during echo.
5. DCM/LHF of any cause
6. Technically inadequate echo.

Study Population

The study population included 100 patients (55 male and 45 female) admitted to the Casualty ward of MGM Medical College & LSK Hospital, Kishanganj, with a first Q wave acute inferior myocardial infarction with or without RVMI.

The patients were divided into two groups:

Group 1 – Patients with IWMI with RVMI (n = 47)

Group 2 – Patients with IWMI without RVMI (n = 53)

Out of the 100 patients, 10 patients (4 from Group 1 & 6 from Group 2) were excluded from the study due to various reasons described below.

- Delayed presentation >2 days after onset of chest pain (n=4)
- Presence of preexisting cardiac dysfunction due to myocardial infarction, cor-pulmonale, DCM or valvular heart disease (n=3)
- Atrial fibrillation (n=1)
- Technically inadequate echo (n=2).

Finally, Group 1 (IWMI with RVMI) consisted of 43 patients and Group 2 (IWMI without RVMI) consisted of 47 patients, and these 90 patients underwent clinical evaluation, investigations including ECG & Echocardiography.

- Detailed history was obtained from all the patients.
- Baseline investigations were done in all patients.
- Cardiac enzymes, namely, Troponin T and CPK-MB were done in all patients.

Patient Characteristics

Patient among the two groups were almost equally distributed age & sex wise, and presence and absence of risk factors with their hemodynamic picture, almost similar and the percentage of patients who were thrombolysed were also almost equal.

Inj. Streptokinase I.V. over 45 minutes via an infusion was given to patients who were eligible candidates for thrombolysis and had no absolute contraindications. All patients were treated with antiplatelets, statins, and fluid replacements whenever needed. Shock patients were managed with fluid replacement and inotropic support.

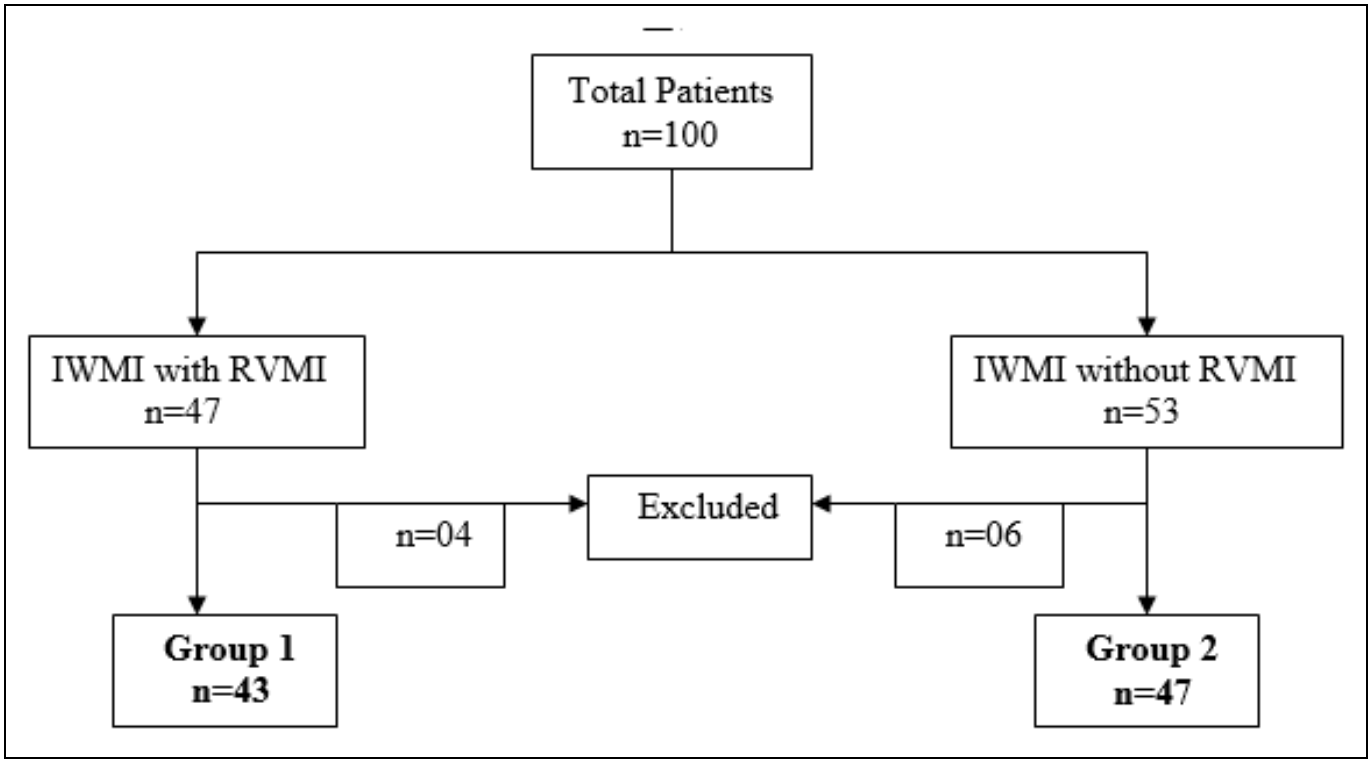

Fig 1

Echocardiography

Transthoracic echocardiography was performed in all patients within 48 hours of symptom onset and whenever possible, within 24 hours, using a Esaote Mylab 40 echocardiography machine with a 3.5 MHz transducer including second harmonic and tissue Doppler imaging technology.

The following measurements were done:

- RV dimensions
- RV contractile function & Inter-ventricular septum movement
- Tricuspid regurgitation jet & Pulmonary artery systolic pressure
- Tricuspid annular movement - M-mode
- Doppler tissue imaging – lateral & septal wall systolic / early, late diastolic velocities
- Myocardial performance index (Tei index)

RV dimensions

It was done using the same M-mode cross-section in the parasternal long axis view. Normal values were defined as less than 27 mm for the right ventricular end diastolic diameter, greater than 36 mm for the left ventricular end diastolic diameter, and less than 0.5 for the ratio of the right ventricular diameter to the left ventricular diameter [11].

Right ventricular contractile function

The motion of Right Ventricular wall was observed in parasternal long axis, parasternal short axis, RV inflow and apical four chamber views. Each segment was analyzed as normal, hypokinetic, akinetic and dyskinetic [11].

Tricuspid regurgitation jet

Peak Velocity of tricuspid regurgitant flow was recorded from apical four chamber view using color doppler and scored as 0-none, 1-mild, 2-moderate and 3-severe TR. Using Bernoulli equation, the systolic tricuspid regurgitation pressure gradient between the RV and the right atrium was noted [11].

Tissue Doppler Index (TDI)

Pulsed wave TDI of the systolic tricuspid annular motion (cm/s) at the lateral free wall (TVlat) and at the septal wall (TVsept) was obtained from the apical 4-chamber view using a pulsed wave dopple, during the early phase (Em) and late phase (Am) of diastolic myocardial velocity [11].

Myocardial Performance Index (MPI)

The myocardial performance index (MPI), or Tei index, is a Doppler echocardiographic parameter and defined as the sum of the isovolumic contraction and relaxation times (ICT and IRT) divided by the ejection time (ET) [12, 13]. MPI, defined as the sum of the ICT and IRT divided by the ET, was obtained from Doppler recordings of left ventricular inflow and outflow [12, 13]. The index was derived as $(a - b)/b$, where 'a' is the interval between the cessation and the onset of the mitral inflow, and 'b' is the ET of the left ventricular outflow [12, 13].

Statistical analysis

Data are presented as mean ± SD for descriptive statistics. We chose the average values for 3-time measurements. Continuous data are expressed as mean ± 1 SD. Comparison of measurements between Group 1 and group 2 was performed using a two tailed Student's *t*-test. A probability (*P*) value of less than 0.05 was considered significant.

Results

75% of the patients belonged to age group of 40-60 years and 76% of the patients were male. 48% patients were diabetic, 36% had hypertension, 55% of patients were chronic smokers, and a family history of ischemic heart disease was noted in 18%.

- Conduction disturbance was a major complication noted among study patients. Conduction disturbances were noted in 36% of Group 1, and in only 08% of patients in Group 2.
- Pulmonary artery systolic pressures >30mmHg were noted in 69% of Group 1, while in Group 2 patients, only 4% had PASP exceeding 30mmHg.
- 7% of Group 1 patients experienced Cardiogenic shock and none of the patients experienced the same in Group 2.
- Deaths due to complications were reported in first week after the onset of acute event in 03 patients, 02 of them belonged to Group 1 while 01 patient died from Group 2.

Electrocardiography

Right Ventricular involvement as defined above by 1mm ST elevation in V4R was seen in 65 patients. 51 patients among them had proximal RCA as the affected vessel on ECG and 14 patients had left circumflex as the vessel causing myocardial infarction.

Echocardiography

Within 48 hours after the onset of the symptoms, Echocardiography was performed in all 100 patients, of which, echocardiography was done within 24 hours of acute event in 61 patients. The results of the Echocardiography are as below:

- In patients with RVMI, RV end-diastolic diameter was increased as compared to those without RV involvement, although the increase was not statistically significant (p=0.1).
- 39% of patients with RVMI reported RV contraction abnormalities and IV septal motion abnormalities, and only in 2% of patients without it.
- The abnormalities in wall motion were noted in patients with their echo done within 24 hours of onset of symptoms, thus concluding that the right ventricle recovers fast after an ischemic episode.

Table 1

Parameters	Group 1	Group 2
RV EDD (mm)	21.6 ± 4.2	11.2 ± 3
RV contraction abnormalities	(39%)	(2%)
IVS motion abnormality	(31%)	(2%)
Tricuspid regurgitation	(50%)	(6%)
PASP (mmHg)	31.6±2.8	17.3 ± 2.6
TAPSE (mm)	14.2 ± 1.3	18.1 ±0.81
MPI	0.45 ± 0.08	0.26 ± 0.04
TDI – RV Free wall Sm (cm/sec) Em Am	9.43 ± 0.50	12.2 ± 0.51
	6.7 ± 0.38	8.2 ± 0.76
	7.4 ± 0.64	9.3 ± 0.71
TDI – Septal wall (cm/sec) Sm	6.4 ± 0.5	6.3 ± 0.5

- The pulmonary artery systolic pressure (PASP) was raised above normal in patients of Group 1 compared to Group 2 but had no statistical significance (p=0.2)
- In nearly 50% of the patients with right ventricular involvement, Tricuspid Regurgitation was noted.
- The tricuspid annular excursion was decreased in patients with right ventricular myocardial infarction, thus concluding that RV systolic function was depressed in those patients. This decrease was statistically significant (p=0.05).
- Myocardial performance index was raised and the rise was statistically significant (p=0.01). It was raised to nearly two-fold the reference values in patients with RVMI; although the values were just slightly higher when compared to controls in those without right ventricular involvement (p=0.01).
- In patients with right ventricular myocardial infarction, tissue doppler showed statistically significant (p=0.02) fall in right ventricular free wall Sm and Em. The values were almost normal in those without RV involvement.

Table: Various echocardiographic parameters in patients presenting with IWMI with or without RVMI

Sub group analysis

- No statistical significance was found in echocardiographic parameters in the various age groups (p=0.5).
- RV dysfunction was almost equally present in both males and females.
- As far as thrombolysis is concerned, RVEDD was higher, Sm & Em values were lower and TAPSE was lower in patients who were thrombolysed, when compared to those who were not; but, was not statistically significant (p=0.2).
- Myocardial performance was statistically significantly low (p=0.04) in patients who were thrombolysed with streptokinase in comparison to non-thrombolysed candidates.
- Significantly lower Sm scores and significantly high MPI scores were noted in patients with right ventricular myocardial infarction with echocardiography done within 24 hours of onset of symptoms.

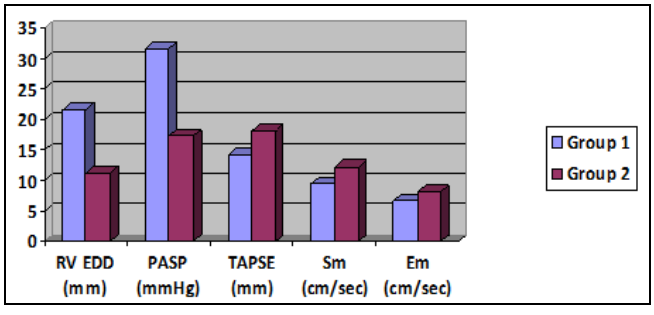

Fig 2

ECG & Echo correlation

- RVMI was found in 03 patients on echo, whose ECG did not show RVMI changes
- 04 patients with RVMI changes on ECG had no evidence of RVMI on echo.

Conclusions

- No significant correlation was found with Age and Sex with right ventricular function after a myocardial infarction.
- On tissue doppler, right ventricular free wall systolic velocity and early diastolic velocity in patients with RVMI was less compared to patients without RVMI and the correlation was statistically significant.
- Right ventricular dimension & contractility were not significant in detecting RVMI.
- Raised MPI values were also associated with higher mortality. Right ventricular myocardial performance index (Tei index) correlated with RV dysfunction and was thus statistically significant
- RV functional abnormality was worse in patients with echo done within 24 hours as compared to the patients in whom echo was done after 24 hours thus concluding that RV function improves with time.
- Echo can detect right ventricular functional abnormality in patients whose ECG shows no or less significant findings of RVMI on ECG.

Discussion

The risk of major complications and deaths is high in patients hospitalized with RVMI.

Clinical implications of RVMI

Hemodynamic insults are associated with RV infarction and it's severity depends upon the extent of RV ischemia, LV function and interventricular dependance.

It has now been proven both experimentally and clinically that the intact LV may also help RV ejection with the aid of LV septal contraction inflicting a bulging into the RV which generates an energetic RV systolic force wave and systolic pressure enough for pulmonary perfusion. lack of this mechanism with concomitant LV infarction, specifically when the interventricular septum is involved, may additionally result in further hemodynamic deterioration in patients with RV infarction. furthermore, augmented atrial contraction is important to overcome the stiffness of the ischemic RV, and factors that impair RV filling (intravascular extent depletion, concomitant atrial infarction, and lack of atrioventricular synchrony) may also critically compromise hemodynamics and lead to cardiogenic shock.

RVMI recovers fast and suffers less ischemic insult because

- Lesser muscle mass and thickness of right ventricle leads to lesser severity of infarct.
- Direct diffusion of oxygen occurs from the right ventricular cavity.
- Coronary perfusion through the Right Coronary artery occurs in both systolic and diastolic phases.

Comparison with other studies

Right ventricular contraction abnormalities

In a study by Dokainish *et al*, 11 out of 22 patients had right ventricular contraction abnormalities (50%) with right ventricular myocardial infarction and only 6 out 28 (20%) patients had right ventricular contraction abnormalities without right ventricular involvement and was thus statistically significant (p=<0.02).

In our study, 39% of patients with RVMI and only 2% of patients without RVMI had RV contraction abnormalities and IV septal motion defects.

Tricuspid regurgitation jet

Anna Vittoria *et al* found that 26 out of 44 patients with right ventricular myocardial infarction had tricuspid regurgitation.

In our study, tricuspid regurgitation was noted in 50% patients with right ventricular involvement.

Tricuspid annular peak systolic excursion (TAPSE)

In a study conducted by Alam *et al*, from the echocardiographic apical 4-chamber views, TAPSE was recorded at the RV free wall with the use of 2-dimensional guided M-mode recordings.

The tricuspid annular motion was reduced in inferior Ml compared with that in healthy individuals (20.5 and 25 mm, P <.001).

In our study, the tricuspid annular excursion was significantly decreased in patients with right ventricular myocardial infarction (14.2 ± 1.3mm Vs. 18.1 ±0.81mm), signifying RV dysfunction in those patients

Myocardial performance index (Tei index)

Tei and coworkers suggested an easily obtainable Doppler-derived index of right ventricular dysfunction, which combined elements of systolic and diastolic function. A RV MPI values of >0.65 is associated with an increased mortality.

Our study showed that MPI had a statistical significance and was 0.45 ± 0.08 in patients with RVMI in comparison of almost normal values of 0.26 ± 0.04 in patients without right ventricular infarction.

Tissue Doppler Imaging

A Swiss study demonstrated that TDI of the systolic lateral tricuspid annular long axis velocity (TVlat) is accurate to characterize systolic RV function independent of most, patho-physiologically meaningful cofactors. A velocity of 12 and 9 cm/s differentiates among normal and moderately reduced RV ejection fraction, respectively between moderately and severely impaired RV EF.

In our study it was found that the right ventricular free wall Sm and Em values were statistically significantly decreased in patients with right ventricular myocardial infarction compared to those without RV involvement. (Sm 9.43 ± 0.50 Vs 12.2 ± 0.51; Em 6.7 ± 0.38 Vs. 8.2 ± 0.76).

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