

Original Research Article

Right ventricular involvement and conduction disturbances in acute inferior wall myocardial infarction patients and their angiographic correlation

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ABSTRACT

Background: Right ventricular myocardial infarction (RVMI) in the setting of inferior wall myocardial infarction (IWMI) is associated with adverse events. The study aimed to evaluate right ventricular (RV) systolic function in the first episode of IWMI by echocardiography; determine incidence of different conduction abnormalities during hospitalization in IWMI patients with and without RVMI; and determine association of these parameters with the location of significant lesion in the infarct related artery.

Methods: This was a prospective study conducted from March 2014 to February 2015. Patients diagnosed with a first episode of acute ST-segment elevation IWMI who presented within 12 hours of symptom onset participated in the study. Patients were divided into two groups according to location of myocardial infarction based on electrocardiographic (ECG) findings. Four echocardiographic parameters of RV systolic function: tricuspid annular plane systolic excursion (TAPSE); systolic excursion velocity of lateral tricuspid annulus (S'); myocardial performance index by pulsed Doppler method (MPI-PD); and right ventricular fraction area change (RV-FAC) were measured.

Results: Clinical presentation such as Kussmaul sign (<0.05), hypotension (<0.05), and raised jugular venous pressure (<0.05) were higher in the IWMI+RVMI group than the IWMI group. ECG-based criteria, ST elevation in V4R to predict RVMI revealed 78.84% sensitivity, 88.86% and 87.46% positive predictive value (p<0.05). TAPSE (13.44±1.46 versus 21.0±1.16 mm, p<0.05), S' (9.03±1.51 versus 16.26±1.21 cm/sec, p<0.05) and RV-FAC (31.24±3.15 versus 47.17±3.65%, p<0.05) were lower in the IWMI+RVMI group compared to the IWMI group.

Conclusions: Cut-off values of TAPSE, S', MPI-PD, and RV-FAC have high sensitivity and specificity for predicting proximal right coronary artery lesions.

Keywords: Echocardiography; Inferior wall myocardial infarction; Right ventricular function; Tissue Doppler imaging

INTRODUCTION

The right ventricle (RV) is less muscular, restricted to pumping blood through a single organ, and less frequently or evidently involved in diseases such as myocardial ischemia or cardiomyopathy compared to the left ventricle. Throughout the years, these aspects have led cardiologists to neglect RV physiology making it a

bystander to left ventricular physiology.¹ However, emerging evidence has highlighted the high rate of adverse events inflicted by right ventricular myocardial infarction (RVMI) in the setting of inferior wall myocardial infarction (IWMI).² Incidence varies from 20-50% predisposing patients to higher risk of hemodynamic instability, conduction disturbances and in-hospital mortality.³

Electrocardiographic (ECG) criteria of ST-segment elevation ≥ 0.1 mV in the right precordial leads (V_4R) is a well-established predictor for the diagnosis of RVMI.⁴ Moreover, the method is easy and cost-effective. Echocardiography is a non-invasive, inexpensive, diagnostic tool widely used in routine clinical practice. Thus, it has been the choice of morphological and functional assessment of the RV in clinical practice. Against this background, we aimed to: (i) evaluate RV systolic function in the first episode of IWMI by echocardiography; (ii) determine incidence of different conduction abnormalities during hospitalization with 12-lead ECG in IWMI patients with and without RVMI; and (iii) determine the association of these parameters with the location of significant lesion in the infarct related artery.

METHODS

Study design and patient population

A prospective study was conducted at a tertiary-care centre in India during the study duration March 2014 to February 2015. A total of 100 consecutive patients diagnosed with a first episode of acute ST-segment elevation IWMI who presented within 12 hours of symptom onset were enrolled in the study. Patients were divided into two groups according to location of myocardial infarction based on ECG findings: (i) group 1 consisted of patients that had presented with isolated IWMI (n=66) and (ii) group 2 consisted of patients that had presented with IWMI with right ventricular myocardial infarction (IWMI+RVMI) (n=34). Acute IWMI was diagnosed by history of ischemic chest pain lasting for a duration of more than 30 minutes with at least 0.1 mV ST-segment elevation at J-point in two contiguous inferior leads (II, III, and aVF) on baseline ECG. RVMI was diagnosed by presence of ST-segment elevation of at least 0.1 mV in right-sided chest lead V_4R on an ECG performed within 6 hours of symptom onset.

Patients with: (i) clinical or electrocardiographic evidence of a previous myocardial infarction; (ii) concomitant acute anterior wall myocardial infarction; (iii) myocardial infarction with location undefinable according to the aforementioned definitions; (iv) previously documented abnormal ventricular function; (v) valvular heart disease; (vi) permanent pacemakers or implantable cardioverter-defibrillators; (vii) left or right bundle branch block; (viii) congenital heart disease; (ix) pulmonary hypertension with RV systolic pressure >40 mmHg on echocardiography; (x) pulmonary embolism; and (xi) poor transthoracic echo window were excluded from the study.

The study was approved by the Institutional Ethics Committee. All patients provided written informed consent for participation in the study prior to commencement of the study.

Assessment of RV systolic function by transthoracic echocardiography

All two-dimensional, M-mode and Doppler echocardiographic measurements were performed according to guidelines of American Society of Echocardiography using Acuson CV0 Echo machine (Siemens) within 12 hours of symptom onset of the patients.⁵ All measurements were repeated thrice and mean values were taken. For assessment of RV systolic function the following parameters were used:

Tricuspid annular plane systolic excursion (TAPSE)

In apical 4-chamber view, M-mode cursor was placed through tricuspid annulus at lateral RV free wall such that the annulus moved along M-mode cursor. The amount of longitudinal motion of annulus at peak systole was measured from M-mode tracing, Total displacement was measured by leading edge of echoes and expressed in millimetre. TAPSE <16 mm was considered abnormal.

Systolic excursion velocity of lateral tricuspid annulus (S')

In apical 4-chamber view the pulsed Doppler sample volume was placed in the tricuspid annulus and pulsed tissue Doppler imaging (TDI) images were acquired. 3.5 mm sample volume was used. As this was a Doppler based technique, proper alignment ($<20^\circ$) with ultrasound beam was considered mandatory. S' velocity <10 cm/sec was considered abnormal.

Myocardial performance index by pulsed Doppler method (MPI-PD)

In apical 4-chamber view, pulsed wave Doppler trans-tricuspid flow velocities were recorded by placing the sample volume between the tricuspid leaflet tips in the centre of the flow stream. Doppler beam was aligned parallel to RV inflow and measurements were taken at end expiration. Tricuspid valve closure- opening time (TCO) was measured as the time interval from tricuspid valve closure marked at the end of A-wave to tricuspid valve opening marked at the beginning of E-wave in the next cardiac cycle in the pulse wave Doppler tracing. Pulsed Doppler of RV outflow was taken by placing the sample volume in RV outflow tract. Ejection time (ET) was calculated as time from onset to cessation of flow. MPI was calculated as TCO-ET/ ET. MPI-PD >0.40 was considered abnormal.

RV fraction area change (FAC)

Calculated as (RV end diastolic area- RV end systolic area)/end diastolic area $\times 100$. RV area in diastole and systole were obtained by tracing the RV endocardium in both phases from the annulus along free wall to apex and then back to annulus along inter ventricular septum in apical 4 chamber view. FAC $<35\%$ was considered

abnormal. In our study, we have operationally defined RV systolic dysfunction in a patient if ≥ 2 of the above mentioned parameters were abnormal.

Coronary angiographic analyses

Angiographic images of the coronary tree were obtained according to standardized procedures with the digital quantitative Siemens Axiom Artis Zee system (Siemens, Germany). Coronary angiography (with or without percutaneous coronary intervention) was performed to detect the culprit lesion within one week after the admission of the patient. Significant lesion/stenosis was defined by the presence of total occlusion, >70% stenosis, acute thrombosis or dissected plaque in the coronary artery assessed on angiography. Proximal left anterior descending (LAD) was defined as the part of LAD artery proximal to and/or including the origin of first septal perforator, mid-LAD was defined as the part distal to the first septal perforator up to second diagonal branch, and distal LAD was defined as the segment after the origin of second diagonal branch. Proximal right coronary artery (RCA) was defined as the part of RCA proximal to and/or including the origin of first major RV branch, mid-RCA was defined as the part distal to the origin of first major RV branch up to the last acute marginal branch, and distal RCA was defined as the segment from the last acute marginal branch to the origin of posterior descending artery. Dominant left circumflex artery (LCx) lesion was defined as significant stenosis in any part of LCx supplying the posterior descending artery.

Statistical analysis

Categorical data are presented as frequencies and percentages. Comparison of categorical variables was performed by Chi-square test. Continuous variables are presented as means \pm standard deviations and analysis was performed using two tailed t-test for equality of means. P value <0.05 was considered as statistically significant. Sensitivity and specificity were calculated using standard formula. All the data were analysed using Statistical Package for the Social Sciences (SPSS; Chicago, IL, USA) program, version 20.

RESULTS

Baseline and clinical characteristics

A total of 218 patients were screened for the study. Out of these 218 patients, 34 met the exclusion criteria, 6 died, 8 refused to undergo coronary angiography, and 70 had significant left main and/or multivessel coronary artery disease and hence were excluded from the study. Of the 100 study participants, 55 (83.3%) and 29 (85.3%) patients were male in the IWMI and IWMI+RVMI groups, respectively. Mean age and body mass index (BMI), and cardiovascular risk factors did not differ significantly between the groups. However, clinical presentation such as Kussmaul sign was observed in 0

and 20 (58.8%) patients, hypotension was observed in 6 (9.1%) and 24 (70.6%) patients, and raised jugular venous pressure (JVP) was observed in 10 (15.2%) and 27 (79.4%) patients in the IWMI and IWMI+RVMI groups, respectively. Clinical presentation for all these variables were statistically significant. The baseline and clinical characteristics of the study population are detailed in Table 1.

Table 1: Baseline and clinical characteristics of the study population.

Variable	IWMI (n=66)	IWMI+RVMI (n=34)	P value
Baseline characteristics			
Age, years	54.95 \pm 9.99	55.18 \pm 10.81	0.672
Body mass index, kg/m ²	23.71 \pm 2.46	23.50 \pm 2.16	0.919
Diabetes mellitus, (%)	26 (39.4%)	16 (47.1%)	0.300
Hypertension, (%)	19 (28.8%)	10 (29.4%)	0.500
Smoking, (%)	39 (59.1%)	24 (70.6%)	0.182
Streptokinase, (%)	59 (89.4%)	30 (88.2%)	0.550
Clinical characteristics			
Kussmaul sign, (%)	0	20 (58.8%)	<0.05
Hypotension, (%)	6 (9.1%)	24 (70.6%)	<0.05
Raised jugular venous pressure, (%)	10 (15.2%)	27 (79.4%)	<0.05
Left ventricular ejection fraction, (%)	58.91 \pm 2.46	54.41 \pm 2.10	<0.05

Data are expressed as number (percentage) or mean \pm SD
 IWMI- inferior wall myocardial infarction, IWMI+RVMI- inferior wall myocardial infarction + right ventricular myocardial infarction.

Sensitivity and specificity of ECG-based criteria

ECG-based criteria, ST elevation in V4R to predict RVMI revealed sensitivity of 78.84%, specificity of 88.68%, and positive predictive value of 87.46% (p<0.05) as shown in Table 2.

Table 2: Sensitivity and specificity of ECG based on the evidence of ST elevation in V4R to predict RVMI.

Variable	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	P value
Evidence of ST-elevation in V4R (>0.1 mV)	78.84	88.68	87.46	<0.05

Incidence of conduction abnormalities

Conduction abnormalities such as atrial fibrillation, first-degree atrioventricular block, type 1 second-degree atrioventricular block, type 2 second-degree atrioventricular block, ventricular tachycardia, and

complete heart block were higher in the IWMI+RVMI group compared to the IWMI group although there was no statistically significant difference. The incidence of conduction abnormalities in both groups is outlined in Table 3.

Table 3: Comparison of different conduction disturbances between the study groups.

Conduction disturbance	IWMI (n=66)	IWMI+RVMI (n=34)	P value
Atrial fibrillation, (%)	5 (7.6%)	4 (11.8%)	0.360
First-degree atrioventricular block, (%)	8 (12.1%)	7 (20.6%)	0.202
Type 1 second-degree atrioventricular block, (%)	10 (15.2%)	8 (23.5%)	0.22
Type 2 second-degree atrioventricular block, (%)	5 (7.6%)	4 (11.8%)	0.362
Ventricular tachycardia, (%)	4 (6.1%)	3 (8.8%)	0.445
Complete heart block, (%)	8 (12.1%)	6 (17.6%)	0.320

Data are expressed as number (percentage)
 IWMI- inferior wall myocardial infarction, IWMI+RVMI- inferior wall myocardial infarction + right ventricular myocardial infarction.

Echocardiographic variables

TAPSE was significantly lower in the IWMI+RVMI group compared to the IWMI group (13.44±1.46 versus 21.0±1.16 mm, p<0.05). S' was also significantly lower in the IWMI+RVMI group compared to the IWMI group (9.03±1.51 versus 16.26±1.21 cm/sec, p<0.05).

Table 4: Comparison of echocardiographic variables of RV systolic function between the study groups.

Variables	IWMI (n=66)	IWMI+RVMI (n=34)	P value
TAPSE, (mm)	21.0±1.16	13.44±1.46	<0.05
S', (cm/sec)	16.26±1.21	9.03±1.51	<0.05
MPI-PD, (n)	0.309±0.023	0.531±0.088	<0.05
RV-FAC, (%)	47.17±3.65	31.24±3.15	<0.05

Data are expressed mean±SD
 IWMI- inferior wall myocardial infarction, IWMI+RVMI- inferior wall myocardial infarction + right ventricular myocardial infarction, TAPSE- tricuspid annular plane systolic excursion, S'- systolic excursion velocity of lateral tricuspid annulus, MPI-PD - myocardial performance index by pulsed Doppler method, RV-FAC- right ventricular fraction area change.

However, MPI-PD was significantly higher in the IWMI+RVMI group compared to the IWMI group

(0.531±0.088 versus 0.309±0.023, p<0.05). RV-FAC was significantly lower in the IWMI+RVMI group compared to the IWMI group (31.24±3.15 versus 47.17±3.65%, p<0.05). The echocardiographic variables of RV systolic function between the study groups are given in Table 4.

Culprit lesion on coronary angiography

Proximal RCA was more often the culprit lesion in the IWMI+RVMI group than the IWMI group. However, mid RCA and distal RCA were more often the culprit lesion in the IWMI group than the IWMI+RVMI group. The comparison of culprit lesion on coronary angiography between the study groups is delineated in Table 5.

Table 5: Comparison of the site of the culprit lesion on coronary angiography in the study groups.

Culprit lesion	IWMI (n=66)	IWMI+RVMI (n=34)
Proximal RCA (n=34), (%)	6 (17.6%)	28 (82.4%)
Mid RCA (n=46), (%)	41 (89.1%)	5 (10.9%)
Distal RCA (n=16), (%)	15 (93.8%)	1 (6.3%)
LCx (n=4), (%)	4 (6.06%)	0

Data are expressed as number (percentage)
 IWMI- inferior wall myocardial infarction, IWMI+RVMI- inferior wall myocardial infarction + right ventricular myocardial infarction, RCA- right coronary artery, LCx- left circumflex artery.

Echocardiographic parameters of RV systolic function with the site of culprit lesion on angiography

TAPSE (14.15±2.70 versus 22.75±0.50 mm), S' (9.65±2.18 versus 17.50±1.29 cm/sec), RV-FAC (32.38±5.20 versus 32.38±5.20%), and LVEF (54.03±1.67 versus 63.50±1.12%) were significantly less in patients with proximal RCA culprit lesion compared to patients with an LCx culprit lesion. However, MPI-PD (0.508±0.113 versus 0.277±0.021) was significantly higher in patients with proximal RCA culprit lesion compared to patients with an LCx culprit lesion. Echocardiographic parameters of RV systolic function with the site of culprit lesion on angiography are detailed in Table 6.

Sensitivity and specificity of echocardiographic parameters to predict proximal RCA lesion

To predict proximal RCA lesions in patients with RVMI, the cut off values of TAPSE, S', MPI-PD and RV-FAC showed good sensitivity (82.4, 82.4, 84.4 and 80.4% respectively) and good specificity (93.9, 95.5, 89.7 and 97.0% respectively). The association of all four parameters with proximal RCA lesion was statistically significant as shown in Table 7.

Table 6: Comparison of echocardiographic parameters of RV systolic function with the site of culprit lesion on angiography.

Echocardiographic variables	Proximal RCA	Mid RCA	Distal RCA	LCx	P value
TAPSE, (mm)	14.15±2.70	20.63±2.38	22.19±2.04	22.75±0.50	<0.05
S', (cm/s)	9.65±2.18	15.50±2.10	16.81±2.00	17.50±1.29	<0.05
MPI-PD, (n)	0.508±0.113	0.327±0.058	0.316±0.038	0.277±0.021	<0.05
RV-FAC, (%)	32.38±5.20	45.35±3.99	49.06±5.87	32.38±5.20	<0.05
LVEF, (%)	54.03±1.67	58.09±1.41	60.94±1.84	63.50±1.12	<0.05

Data are expressed mean ± SD

IWMI- inferior wall myocardial infarction, IWMI+RVMI- inferior wall myocardial infarction + right ventricular myocardial infarction, TAPSE- tricuspid annular plane systolic excursion, S'- systolic excursion velocity of lateral tricuspid annulus, MPI-PD- myocardial performance index by pulsed Doppler method, RV-FAC- right ventricular fraction area change, RCA- right coronary artery, LCx- left circumflex artery.

Table 7: Sensitivity and specificity of echocardiographic parameters to predict proximal RCA lesion.

Variable	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	P value
TAPSE (<16 mm)	82.4	93.9	87.5	91.2	<0.05
S' (<10 cm/sec)	82.4	95.5	90.3	91.3	<0.05
MPI-PD (>0.400)	84.4	89.7	84.4	89.7	<0.05
RV- FAC (<35%)	80.4	97.0	93.33	91.42	<0.05

TAPSE- tricuspid annular plane systolic excursion, S'- systolic excursion velocity of lateral tricuspid annulus, MPI-PD- myocardial performance index by pulsed Doppler method, RV-FAC- right ventricular fraction area change, RCA- right coronary artery, LCx- left circumflex artery.

DISCUSSION

The present study assessed RV systolic function in the first episode of IWMI using four echocardiographic parameters of RV systolic function: TAPSE, S', MPI-PD, and RV-FAC. Among these, M-mode measurement of TAPSE and S' have a proven role in assessing regional as well as global RV systolic function. Bayata et al reported 16.2±2.0 and 21.6±2.1 mm in IWMI patients with and without RVMI, respectively.⁴ Similarly, Alam et al reported 17±2.8 and 22.7±4.9 mm respectively.⁶ In concordance with these findings, TAPSE was 13.44±1.46 and 21.0±1.16 mm, respectively in our study. A similar trend was observed with S'. Bayata et al indicated S' as 11.0±12.6 and 136.1±8.8 mm/s in IWMI patients with and without RVMI, respectively.⁴ Mukhaini et al reported S' as 11.1±2.9 and 14.0±1.9 cm/s, respectively.⁷ In line with these findings our study reported S' as 9.03±1.51 and 16.26±1.2 cm/sec, respectively. Other variables assessed were MPI-PD reported as 0.531±0.088 and 0.309±0.023 which are congruent with the findings of El Missiri et al who indicated MPI-PD of 0.4±0.08 and 0.31±0.05 in IWMI patients with and without RVMI, respectively.²

We also determined the incidence of different types of conduction disturbances in both the study groups during the period of hospitalization using 12-lead ECG. Incidence of patients with second-degree atrioventricular block was 35.3% and 12.8% in IWMI patients with and without RVMI, respectively. The same trend was observed by Pirzada et al.⁸ Incidence of ventricular

tachycardia was 8.8% and 6.1% in IWMI patients with and without RVMI, respectively. These findings are concordant with that of Kukla et al who reported ventricular tachycardia of 7.6% and 2.1%, respectively.³ Similarly, Samadikhah et al revealed ventricular tachycardia incidence of 27% and 12.9% in IWMI patients with and without RWMI, respectively.⁹ George et al concluded ventricular tachycardia incidence of 24% and 9% in IWMI patients with and without RWMI, respectively.¹⁰

ST-segment elevation in electrocardiographic lead V_{4R} is the single most powerful predictor of right ventricular involvement in the setting of IWMI. The sensitivity of this finding is lower than specificity even when strictly employed. In our study, sensitivity and specificity of ECG to predict proximal RCA lesion was 78.8% and 88.7%, respectively. Similarly, a study by Klein et al revealed sensitivity and specificity of 83% and 77%, respectively.¹¹ Rajesh et al found the sensitivity of ECG to be 76%.¹²

Our study had a few limitations. Firstly, the study population was very small (100 patients) and hence further studies in a larger population are required. Secondly, our study did not have any control group to compare the RV systolic function which would have given a better insight in the pattern of affection of RV function in MI. Thirdly, echocardiography was done within 12 hours of symptom onset of a patient but in many patients due to the delay in performing echocardiography, we might have missed RV systolic

dysfunction as its recovery is very fast in some cases. Fourth, echocardiographic assessment should ideally be performed before any reperfusion strategy as there is a possibility of recovery of RV function. However, it was considered unethical to delay reperfusion for echocardiographic assessment. Also, coronary angiography performed later might have missed some cases with a proximal RCA occlusion because of spontaneous recanalization.

CONCLUSION

Our study revealed one-third patients with IWMI have associated RVMI. Its clinical diagnosis is ascertained by the presence of hypotension, raised JVP and Kussmaul's sign. ST-segment elevation in lead V4R in ECG is highly specific for the diagnosis of RVMI in patients presenting with acute IWMI. Conduction disturbances are also found with increased frequency in patients with RVMI in the setting of IWMI. Furthermore, patients with a culprit lesion in proximal RCA are significantly more likely to develop RVMI in association with IWMI. Parameters of RV systolic function are significantly abnormal in patients of RVMI and in patients with a culprit lesion in proximal RCA. Cut-off values of these four parameters of RV systolic dysfunction namely TAPSE, S', MPI-PD, and RV-FAC have high sensitivity and specificity for predicting proximal RCA lesion.

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