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ORIGINAL ARTICLE

Study of Right Ventricular Strain Imaging in Patients with Acute Inferior Wall Myocardial Infarction in a Tertiary Care Hospital in Eastern India

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Abstract

Background: Right ventricle (RV) involvement in inferior wall myocardial infarction (IWMI) is considered a strong predictor of in-hospital mortality and complications. However, assessment of RV involvement and function remains challenging due to difficulties in chamber visualization.

Objective: This study aimed to assess RV involvement in patients with IWMI using myocardial wall velocity (tissue Doppler imaging) and strain rate parameters with conventional echocardiographic indices, evaluating RV function and its correlations with in-hospital mortality and morbidity.

Methods: An observational study was conducted from May 2020 to April 2021 in 210 patients with IWMI visiting a tertiary care center. For each participant, demographics and clinical characteristics were obtained, and an electrocardiography (ECG) was recorded. Following this, right ventricular global longitudinal strain (RVGLS) and echocardiographic parameters (Tei index, right ventricular fractional area change [RVFAC], and tricuspid annular plane systolic excursion [TAPSE]) were estimated. Chi-square test was performed for differences in outcomes between patients with and without RV dysfunction. Correlation analysis was conducted between RVGLS, ECG, and other echocardiographic parameters. $P < 0.05$ was considered statistically significant.

Results: Pearson's correlation analysis between RVGLS and Tei index among patients with IWMI indicated a moderate negative correlation ($R = 0.610$). Furthermore, RVGLS exhibited a moderate positive correlation with RVFAC ($R = 0.635$) and TAPSE ($R = 0.718$). At the cutoff of −16.75, RVGLS predicted RV involvement in patients with 97.0% sensitivity and 68.7% specificity. RVGLS predicted RV dysfunction in 44.8% of the patients in the mortality group.

Conclusion: RVGLS can be used as an alternative measure for predicting RV involvement in patients with IWMI.

Keywords: Myocardial Infarction; Inferior Wall Myocardial Infarction; Right Ventricular Dysfunction.

Introduction

Myocardial infarction (MI) refers to necrosis of the myocardium due to sudden occlusion of blood flow to the myocardium.[1] This results in death and necrosis of the affected myocardium.[1] The most common causes of MI are atherosclerosis and coronary artery disease.[2] About one third of the patients with inferior MI have right ventricle (RV) dysfunction.[3] RV involvement in patients with inferior MI has been described as a strong predictor of in-hospital mortality and major complications.[4] Right ventricular MI commonly occurs with inferior wall myocardial infarction (IWMI) and is associated with a significant increase in mortality and morbidity.[5]

The role of echocardiography has enhanced with an increase in its availability.[6] However, assessing the RV and its function remains challenging due to difficulty in the visualization of the chamber.[7] Imaging of the RV is difficult owing to its complex crescent-shaped structure, heavy trabeculation, and retrosternal location.[8] Echocardiographic strain and strain rate imaging are novel

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Central Illustration: Study of Right Ventricular Strain Imaging in Patients with Acute Inferior Wall Myocardial Infarction in a Tertiary Care Hospital in Eastern India

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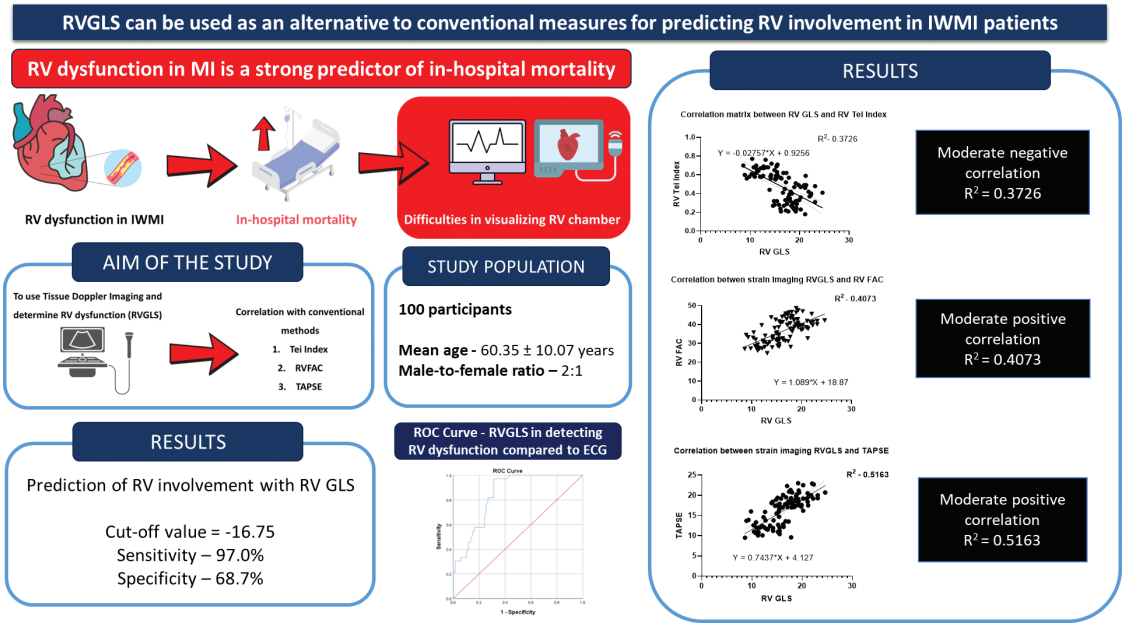

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RVGLS: right ventricular global longitudinal strain; RV: right ventricle; GLS: global longitudinal strain; FAC: fractional area change; TAPSE: tricuspid annular plane systolic excursion; ROC: Receiver Operating Characteristic.

techniques for the assessment of myocardial function.[9] Longitudinal strain, which can be measured by tissue Doppler imaging and 2-dimensional speckle tracking, is a reliable and accurate way to measure RV systolic function and has been validated in an animal study with sonomicrometry and cardiac magnetic resonance (CMR) for several human cardiovascular diseases.[10]

In this study, we aimed to assess RV involvement in patients with IWMI using myocardial wall velocity (tissue Doppler imaging) and strain rate parameters with conventional echocardiographic indices, evaluating RV function and its correlations with short-term outcomes within hospital mortality and morbidity.

Methodology

An observational study was conducted from May 2020 to April 2021 in 210 patients with inferior MI admitted to the cardiology department in a tertiary care center. Convenience sampling was used, and all patients diagnosed to have COVID-19 infection at admission, electrocardiography (ECG) evidence of left bundle branch block, history of previous MI, cor pulmonale, suspected pulmonary embolism, pulmonary hypertension, associated pericardial disease, and amyloidosis were excluded from the study.

Informed written consent was obtained from every participant as per the modified Indian Council of Medical Research template. The Institutional Ethics Committee approved the study.

The sociodemographic features and baseline clinical characteristics were recorded for each study individual. The features and values that were used to diagnose RV dysfunction in the present study are based on the following established criteria provided in Table 1.

Data analysis

All data were entered into Microsoft Excel (Microsoft Inc.), double-checked for correctness, and analyzed using SPSS software. Categorical variables were expressed as absolute (N) and relative frequencies (%); continuous variables were expressed as mean ± standard deviation. Associations were determined between RVGLS and outcomes such as death, discharge, temporary cardiac pacing (TCP) required, TCP not required, fluid requirement ≤ 3 days or > 3 days, and vasopressor

requirement. Chi-square test was used to determine statistical significance. A p value < 0.05 was considered to be statistically significant.

A receiver operating characteristic curve was used to indicate the sensitivity and specificity of the diagnostic approaches considered. A linear relationship between independent predictors (namely RV Tei index, right ventricular fractional area change [RVFAC] index, and tricuspid annular plane systolic excursion [TAPSE]) and RVGLS was assumed, and, after testing for the normal distribution of residuals, simple linear regression (Pearson's correlation) was conducted to determine the correlation between the diagnostic approaches. Correlation analysis was conducted between strain imaging (RVGLS) and other echocardiographic parameters including ECG, Tei index, RVFAC, and TAPSE. A p value < 0.05 was considered statistically significant.

Table 1 – Features and values used to diagnose RV dysfunction.

Criteria	RVMI	No RV involvement
ECG	ST elevation in V1 ST elevation in V1 and ST depression in V2 (highly specific for RV infarction) Isoelectric ST segment in V1 with marked ST depression in V2 ST elevation in III > II Diagnosis is confirmed by the presence of ST elevation in the right-sided leads (V3R-V6R).	-
Tei index	≤ 0.40	> 0.40
RVFAC	≤ 35%	> 35%
TAPSE	< 15 mm	≥ 15 mm

ECG: electrocardiography; RV: right ventricle; RVFAC: right ventricular fractional area change; RVGLS: right ventricular global longitudinal strain; RVMI: right ventricular myocardial infarction; TAPSE: tricuspid annular plane systolic excursion; ST: ST segment of ECG.

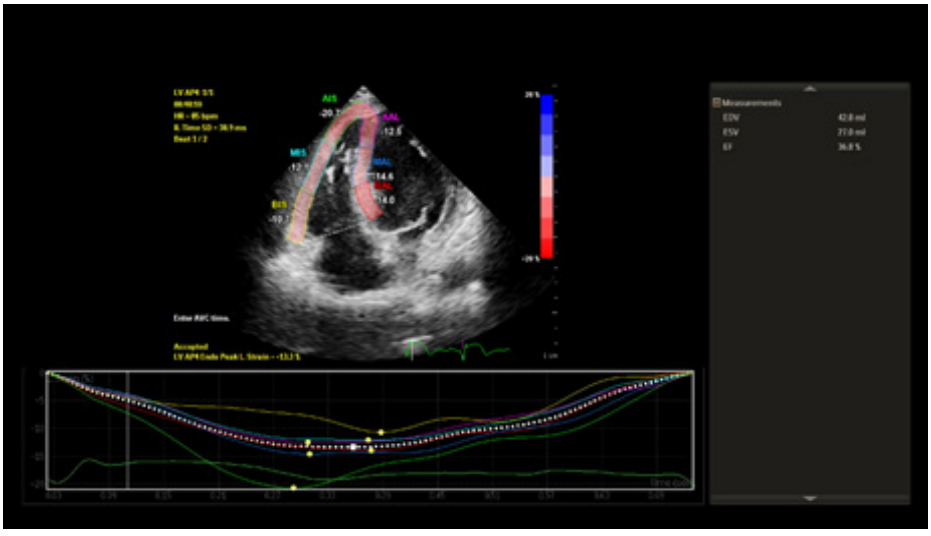

Figure 1 – A representative image of RV involvement in IWMI

Table 2 – Demographics

Age groups (years)	N (%)
≤ 40	3 (3)
41 to 50	16 (16)
51 to 60	32 (32)
61 to 70	36 (36)
≥ 71	13 (13)
Males	68 (68)
Females	32 (32)
Smokers	34 (34)
Hypertension	35 (35)
Type 2 diabetes mellitus	31 (31)

Results

A total of 100 individuals out of 210 study participants had IWMI (Figure 1). More than one third of the participants were 61 to 70 years old. The mean age of the participants was 60.35 ± 10.07 years. The male-to-female ratio was 2:1. Table 2 provides the demographics of the study population. More than one third of the participants smoked tobacco regularly. Around 60% of the participants suffered from hypertension and diabetes. Table 3 indicates the frequency of the RV involvement parameters.

Comparison of right ventricular strain imaging with conventional parameters for identifying right ventricular involvement

Figure 2 shows the sensitivity and specificity of RVGLS in predicting RV involvement among the patients as compared to ECG. At the cutoff of −16.75, patients with RV involvement can be predicted with 97.0% sensitivity and 68.7% specificity. The area under the curve (AUC) is 0.844 (0.771, 0.918).

Figure 3 shows the correlation between the RVGLS measurement and the Tei index in the detection of RV involvement in patients with IWMI. There was a moderate negative correlation between the two, with a Pearson's correlation coefficient (R) of 0.610.

Figure 4 shows the sensitivity and specificity of RVGLS in predicting RV involvement among the patients as compared to the Tei index. At the cutoff of −18.85, patients with RV involvement can be predicted with 61.1% sensitivity and 18.7% specificity. The AUC is 0.230 (0.138, 0.323).

Figure 5 shows the correlation between the RVGLS measurement and RVFAC in the detection of RV involvement in patients with IWMI. A moderate positive correlation was observed between them, with a Pearson's correlation coefficient (R) of 0.635.

Figure 6 shows the sensitivity and specificity of RVGLS in predicting RV involvement among patients with IWMI as compared to RVFAC. At the cutoff of −16.75, patients with RV involvement can be predicted with 90.9% sensitivity and 76.8% specificity. The AUC is 0.889 (0.823, 0.955).

Figure 7 shows the correlation between RVGLS and TAPSE in the detection of RV involvement in patients with IWMI. There was a moderate positive correlation between the two, with a Pearson's correlation coefficient (R) of 0.718.

Figure 8 shows the sensitivity and specificity of RVGLS in predicting RV involvement among the patients as compared to TAPSE. At the cutoff of −16.47, patients with RV involvement can be predicted with 91.9% sensitivity and 73% specificity (Table 4). The AUC is 0.901 (0.844, 0.959).

Discussion

In our study, we assessed RV involvement in patients with IWMI using myocardial wall velocity and strain rate parameters. We found that RVGLS can be used for the assessment of RV involvement with a sensitivity of 81% and specificity of 95% in patients

Table 3 – Right ventricular involvement parameters

Parameters	N (%)
ECG	33 (33)
Tei index present (< 0.40)	36 (36)
RVFAC present (< 35%)	44 (44)
RVGLS (–16.47)	51 (51)
TAPSE (< 1.5 cm)	37 (37)

ECG: electrocardiography; RVFAC: right ventricular fractional area change; RVGLS: right ventricular global longitudinal strain; TAPSE: tricuspid annular plane systolic excursion.

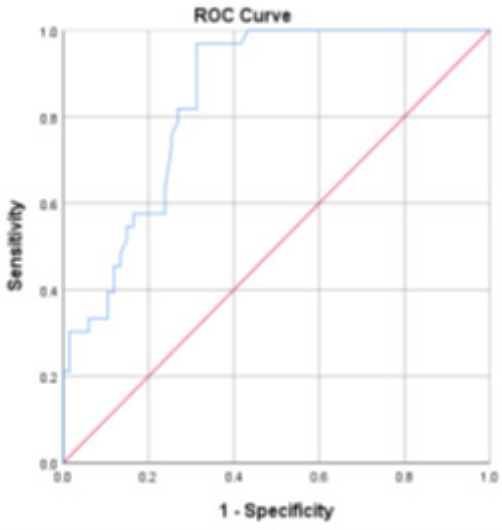

Figure 2 – Receiver operating characteristic curve showing sensitivity and specificity of strain imaging (right ventricular global longitudinal strain — RVGLS) in detecting right ventricular involvement as compared to ECG.
ROC: Receiver Operating Characteristic.

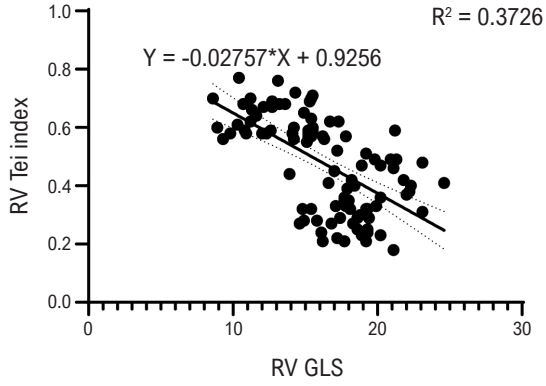

Figure 3 – Correlation between strain imaging (RVGLS) and Tei index in detecting RV involvement in patients
RV: right ventricle; RVGLS: right ventricular global longitudinal strain.

with ST-elevation myocardial infarction (STEMI). The Central Illustration summarizes the key findings of our study.

Acute IWMI is usually due to occlusion of the right coronary artery.[11] ECG is a valuable, non-invasive, easily repeatable, and inexpensive means of diagnosing RV involvement.[12] ST-segment elevation in lead V4R has an overall sensitivity of 88%, specificity of 78%, and diagnostic accuracy of 83%.[13]

Generally, around 14% to 84% of patients with IWMI show RV involvement.[14,15] In the present study, RV involvement was seen in 33% of the patients based on their ECG. A study conducted in Pakistan reported RV involvement in 34% of the cases based on ECG reports.[16] Another study from South India showed that 40% of patients with acute IWMI had RV involvement based on the ECG criteria.[17] In our study, peak incidence was found in the age group 61 to 70 years. In a study conducted in India, the highest number of patients were in the 51 to 70 years age group, indicating that elderly individuals are at higher risk.[17]

The RV has a complex anatomy and different systolic motion; thus, echocardiographic measurement of RV systolic function is challenging in routine echocardiographic examination.[10] The superficial location of the RV just beneath the sternum is another obstacle in echocardiographic evaluation.[7] There is no single best

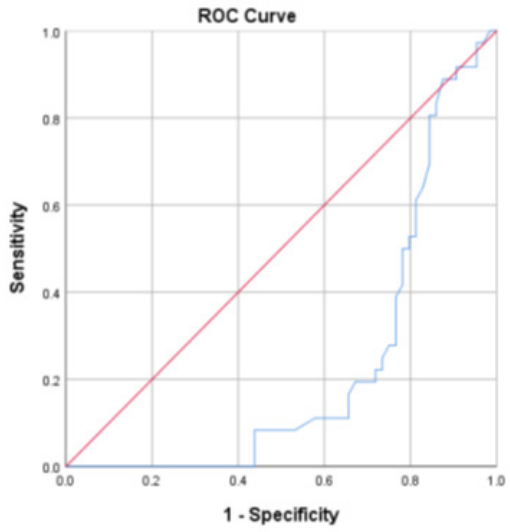

Figure 4 – Receiver operating characteristic curve showing sensitivity and specificity of strain imaging (RVGLS) in detecting right ventricular involvement as compared to Tei index.

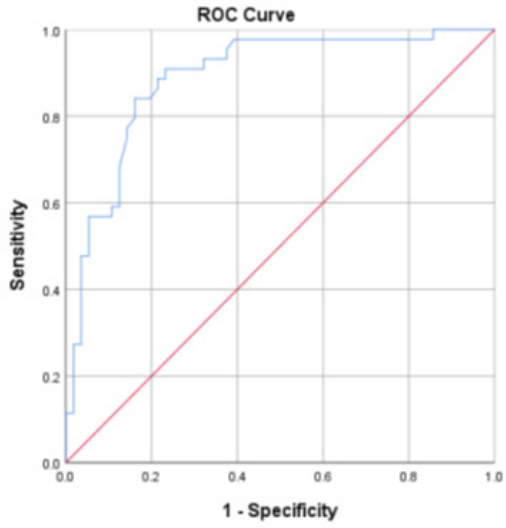

Figure 6 – Receiver operating characteristic curve showing sensitivity and specificity of strain imaging (RVGLS) in detecting right ventricular involvement as compared to RVFAC
ROC: Receiver Operating Characteristic.

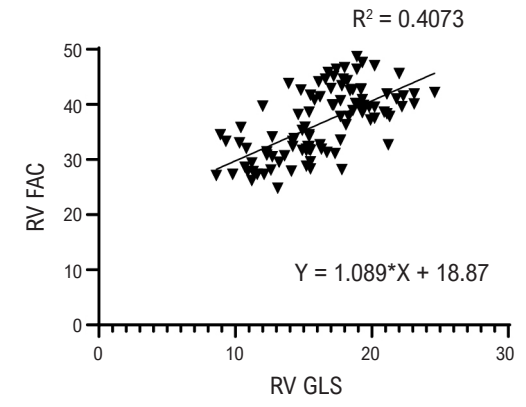

Figure 5 – Correlation between strain imaging (RVGLS) and RVFAC in detecting right ventricular involvement in patients
RVFAC: right ventricular fractional area change; RVGLS: right ventricular global longitudinal strain.

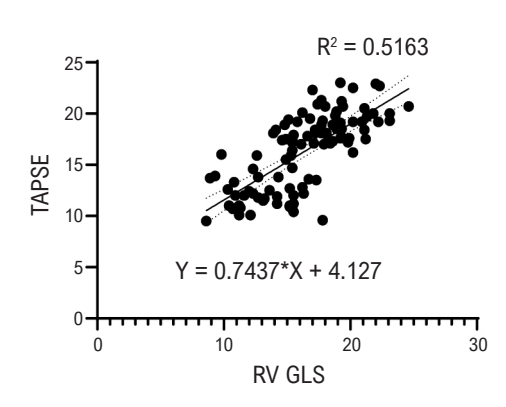

Figure 7 – Correlation between strain imaging (RVGLS) and TAPSE in detecting right ventricular involvement in patients
RVGLS: right ventricular global longitudinal strain; TAPSE: tricuspid annular plane systolic excursion.

echocardiographic indicator of RV systolic function due to the complex shape of the chamber.[4,10] Thus, several echocardiographic indices of RV systolic function are currently used. RVFAC, TAPSE, and RV Tei index are the commonly measured parameters that have been reported in the present study.

RVGLS has been used to assess the RV in various disease categories but has not previously been validated in patients with IWMI with RV involvement. The muscle fibers of the RV predominantly run in a longitudinal direction, and the major RV contractility occurs in the longitudinal plane; GLS can represent RV function accurately.[18] Moreover, strain has the advantage of distinguishing the true contractility of the free wall rather than tethering or translational motion which can influence indices like TAPSE.[19]

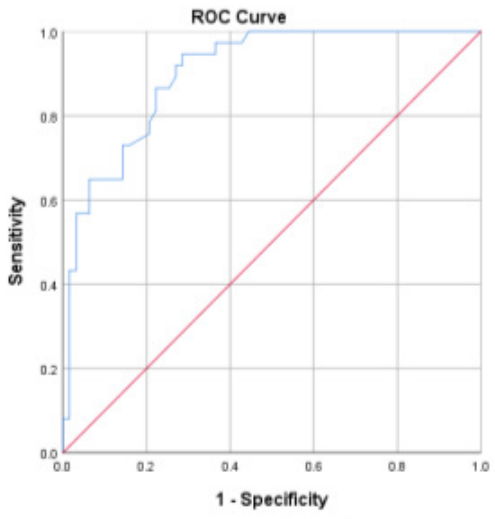

Figure 8 – Receiver operating characteristic curve showing sensitivity and specificity of strain imaging (RVGLS) in detecting right ventricular involvement as compared to TAPSE
ROC: Receiver Operating Characteristic.

In the present study, RVGLS had a moderate positive correlation with the Tei index (r = 0.610, p < 0.001) and moderate negative correlations with RVFAC (r = −0.635, p < 0.001) TAPSE (r = −0.718, p < 0.001).

In a study undertaken to validate the GLS and strain rate as reliable markers for RV dysfunction, RVGLS showed similar significant correlations with RVFAC (r = −0.530, p < 0.01), and TAPSE (r = −0.547, p < 0.01).[20] RVGLS has also been significantly correlated with TAPSE (r = −0.547 to −0.83), RVFAC (r = −0.213 to −0.73), tricuspid S' velocity (r = 0.718), and RV Tei index (r = 0.590), when measured by CMR.[10]

Park et al.,[21] reported the best cutoff value of RVGLS for the detection of RV dysfunction as −15.4% (AUC = 0.955, p < 0.01), with a sensitivity of 81% and specificity of 95% when CMR was considered the gold standard for comparison. RVGLS showed significant correlations with CMR-measured RV ejection fraction (r = −0.797, p < 0.01), RVFAC (r = −0.530, p < 0.01), and TAPSE (r = −0.547, p < 0.01).

In another group of adolescents and young adult patients operated on for tetralogy of Fallot, according to receiver operating characteristics analysis, an RVGLS cutoff value of −17.4% had 75% sensitivity and 68.4% specificity in identifying RV ejection fraction < 45% with AUC 0.743 (p < 0.05) compared to a gold standard of CMR.[22] Lee et al. reported that the best cutoff value of RVGLS for detection of RV dysfunction was −15.4% (AUC = 0.955, p < 0.01), with a sensitivity of 81% and specificity of 95%.[10]

The clinical importance of RV function in patients with STEMI has been underestimated in the past. This is related to a more difficult assessment of RV function compared to the left ventricle, which needs a multi-parametrical approach using both conventional 2-dimensional and speckle-tracking echocardiography.[7,10,21] In patients with acute inferior STEMI, RV involvement has been defined as a strong predictor of in-hospital major complications and mortality.[23] Reduced RVGLS is a strong independent predictor of adverse events in post-AMI patients, and RV strain was demonstrated to be of incremental value in addition to other traditional parameters.[24]

We studied the correlation of short-term clinical outcomes based on the presence of ventricular dysfunction as measured by an RVGLS cutoff of −16.47. This value was used as the cutoff because the highest sensitivity and specificity of diagnosis of ventricular dysfunction were obtained at this cutoff using the Tei index as the gold standard.

Table 4 – Summary table showing the sensitivity and specificity of RVGLS compared to ECG and conventional echo parameters.

	Cutoff	Sensitivity (%)	Specificity (%)	AUC	Low	High	p value
ECG (N = 33)	−16.75	97	68.7	0.844	0.771	0.918	< 0.001*
Tei index (N = 37)	−18.85	61.1	18.7	0.230	0.138	0.323	< 0.001*
RVFAC (N = 44)	−16.75	90.9	76.8	0.889	0.823	0.955	< 0.001*
TAPSE (N = 36)	−16.47	91.9	73	0.901	0.844	0.959	< 0.001*

AUC: area under the curve; ECG: electrocardiography; RVFAC: right ventricular fractional area change; RVGLS: right ventricular global longitudinal strain; TAPSE: tricuspid annular plane systolic excursion.

Table 5 – Correlation of parameters with presence of RV dysfunction as per RVGLS in patients

Parameters	RV dysfunction**		$\chi 2$	p value
	Present (%)	Absent (%)		
Discharge (n = 87)	39 (44.8)	48 (55.2)	10.203	0.002*
Death (n = 13)	12 (92.3)	1 (7.7)		
TCP required (n = 21)	21 (100)	0 (0)	25.54	<0.001*
TCP not required (n = 79)	30 (38)	49 (62)		
FR ≤ 3 days (n = 66)	18 (27.3)	48 (72.7)	43.732	<0.001*
FR > 3 days (n = 34)	33 (97.1)	1 (2.9)		
Vasopressor not required (n = 82)	34 (41.5)	48 (58.5)	16.579	<0.001*
Vasopressor required (n = 18)	17 (94.4)	1 (5.6)		

FR: fluid requirement; RV: right ventricle; RVGLS: right ventricular global longitudinal strain; TCP: temporary cardiac pacing.

Table 6 – Comparison of outcome of patients based on ECG, conventional criteria, and RVGLS

Variables	Death (n = 13)		Hospital stay >7 d (n = 29)		TCP (n = 21)		Fluid > 3 days (n = 34)		Vasopressor (n = 18)	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
ECG (n = 33)	8 (61.5)	25 (28.7)	17 (58.6)	16 (22.5)	12 (57.1)	21 (26.6)	22 (64.7)	11 (16.7)	9 (50)	24 (29.3)
TAPSE (n = 37)	13 (100)	24 (27.6)	23 (79.3)	14 (19.7)	16 (76.2)	21 (26.6)	8 (23.5)	55 (83.3)	14 (77.8)	23 (28)
RVFAC (n = 44)	12 (92.3)	32 (36.8)	26 (89.7)	18 (25.4)	16 (76.2)	28 (35.4)	27 (79.4)	17 (25.8)	14 (77.8)	30 (36.6)
Tei index (n = 36)	0 (0.0)	36 (41.4)	2 (6.9)	34 (47.9)	2 (9.5)	34 (43.0)	3 (8.8)	33 (50.0)	2 (11.1)	34 (41.5)
RVGLS (n = 51)	12 (92.3)	39 (44.8)	28 (96.6)	23 (32.4)	21 (100)	30 (38.0)	33 (97.1)	18 (27.3)	17 (94.4)	34 (41.5)

ECG: electrocardiography; RVFAC: right ventricular fractional area change; RVGLS: right ventricular global longitudinal strain; TAPSE: tricuspid annular plane systolic excursion; TCP: temporary cardiac pacing.

Almost half of the patients who died had RV dysfunction (44.8%), and 96.6% of patients with RV dysfunction had a hospital stay of > 7 days. All of them required TCP; 97.1% of patients required intravenous fluids for > 3 days, and 94.4% of patients required vasopressors (Tables 5 and 6). Multivariable analysis, adjusted for other variables that predicted adverse outcomes, in a study[24] on 502 consecutive patients presenting with a first acute STEMI and treated with primary percutaneous coronary intervention within the first 12 hours, showed that RVGLS > −17% ($p < 0.001$) was a strong independent predictor of an in-hospital major adverse cardiac event. However, this study included cases that had RV involvement regardless of the localization of the MI.

The present study was a single-center, observational study with a relatively low sample size. Since strain imaging highly depends on frame rate and image resolution, endocardial border tracing had to be performed manually. As dedicated software for 2-dimensional RV strain was not available, we used a scheme designed for speckle tracking of the left ventricle. The echocardiographic protocol did not include 3-dimensional acquisitions; therefore, data on RV volumes and ejection fraction could not be acquired.

Several other factors such as age, sex, presence of comorbidity, smoking, medications, type of procedure performed, and concomitant left ventricular involvement may influence the outcome of patients with IWMI and RV dysfunction. These factors have not been included in the present analysis and could have affected the outcome of a multivariable analysis.

Conclusion

The present analysis reveals that RVGLS can be used as an alternative to conventional parameters based on the sensitivity and specificity of RVGLS compared to conventional measures. TAPSE was found to be a superior conventional parameter for the detection of RV dysfunction in relation to Tei index and RVFAC. In-hospital adverse outcomes can be predicted to a similar extent based on the suggested cutoff, as compared to the ECG and conventional echocardiographic parameters. However, larger studies are required to validate the result in a larger population.

Author Contributions

Conception and design of the research, acquisition of data, analysis and interpretation of the data, statistical analysis, writing of the manuscript and critical revision of the manuscript for intellectual content: Biswas P, Chakraborty S, Majumder B.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

This study is not associated with any thesis or dissertation work.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the RG Kar Medical College and Hospital under the protocol number RKC/187. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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