Section: Cardiology

Original Research Article

USEFULNESS OF PULMONARY REGURGITATION DOPPLER TRACINGS IN PREDICTING OUTCOME IN PATIENTS WITH ACUTE INFERIOR WALL MYOCARDIAL INFARCTION

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Received : 01/06/2025
Received in revised form : 19/07/2025
Accepted : 06/08/2025

Keywords:
Fractional area change, Inferior wall myocardial infarction, Pressure half-time, Pulmonary regurgitation.

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DOI: 10.47009/jamp.2025.7.4.259

Source of Support: Nil,
Conflict of Interest: None declared

Int J Acad Med Pharm
2025; 7 (4); 1362-1368

ABSTRACT

Background: Pulmonary regurgitation (PR) flow-derived Doppler tracings are a valuable tool in identifying right ventricular (RV) involvement during the early phase of acute myocardial infarction (AMI), particularly within the first 24 hours. The PR Doppler flow pattern is closely influenced by the diastolic pressure profile of the RV, which undergoes significant alterations during AMI, thereby modifying the regurgitant flow characteristics. Aim: To evaluate Doppler-derived parameters of PR and assess their prognostic significance in patients with acute myocardial infarction (AMI), specifically in the context of inferior wall MI (IWMI). **Materials and Methods:** This prospective study was conducted in the Intensive Coronary Care Unit (ICCU) at Government Coimbatore Medical College Hospital. All patients underwent clinical evaluation, electrocardiography (ECG), two-dimensional and Doppler echocardiography, and coronary angiography. RV involvement was assessed using both ECG and echocardiographic criteria. Patients were divided into two groups based on PR pressure half-time (PHT): Group 1: PHT ≤ 150 ms (n = 66) and Group 2: PHT > 150 ms (n = 58). **Result:** Significant differences were observed between the two groups in the following RV function parameters: RV dimension, RV/LV ratio, RV fractional area change (FAC), RV ejection fraction, tricuspid annular plane systolic excursion (TAPSE), mitral annular systolic velocity (MASV), and RV Tei index (P < 0.05). PR peak velocity and end-diastolic velocity showed no significant differences; however, mid-diastolic minimum velocity was significantly lower in Group 1 (0.42 m/s) compared to Group 2 (0.80 m/s, P < 0.0001). The mean PHT was 101.2 ms in Group 1 and 226 ms in Group 2.In-hospital complications occurred in 53 patients (42.7%), with a significantly higher incidence in Group 1 (55.8% vs. 27.4%, P = 0.012).Significant predictors of in-hospital events included: Age > 65 years (P = 0.049) • ST elevation in lead V4R (P = 0.018). • RV dilatation on echocardiography (P = 0.020). • PR Doppler criteria: PHT ≤ 150 ms (P = 0.020). • Combined Vmin/Vmax ≤ 0.5 and PHT ≤ 150 ms (P = 0.044). • Triple vessel disease on coronary angiogram (P < 0.0001). **Conclusion:** In patients with acute inferior wall myocardial infarction, Doppler evaluation of pulmonary regurgitation is a valuable non-invasive tool for predicting in-hospital complications. PR-derived Doppler parameters—particularly PHT ≤ 150 ms and Vmin/Vmax ≤ 0.5—serve as strong predictors of both RV involvement and adverse clinical outcomes.

INTRODUCTION

Acute myocardial infarction (AMI) affecting the right ventricle (RV) almost always occurs alongside an inferior wall infarction of the left ventricle (LV). While the impact of LV dysfunction on patient outcomes post-AMI is well established, there is limited data regarding the prognostic significance of RV dysfunction. A recent study by Pfisterer et al. highlighted that reduced RV ejection fraction

independently contributes to the risk of cardiac death following myocardial infarction, even when LV function is accounted for. Therefore, bedside-accessible, non-invasive hemodynamic assessments could play a critical role in early identification of high-risk patients with RV involvement during the acute phase of MI. Zehender et al. found that ST-segment elevation in lead V4R upon admission strongly predicted in-hospital complications. However, the reliability of non-invasive diagnostic tools varies across studies. Echocardiographic evaluation of the RV may serve as a useful alternative, though it presents challenges due to suboptimal imaging windows and the complex structure of the RV. Continuous wave Doppler assessment of physiologic pulmonary regurgitation (PR) has emerged as a promising method, as PR flow directly correlates with the pressure difference between the pulmonary artery and the RV, in accordance with the Bernoulli equation. During the initial 24 hours following AMI, PR Doppler waveforms have proven effective in detecting RV involvement. The PR Doppler profile largely reflects the RV diastolic pressure pattern, which is typically disrupted during RV ischemia and marked by an elevated RV end-diastolic pressure. Based on this physiological relationship, we hypothesized that changes in RV pressure would influence the characteristics of the regurgitant flow. To explore this theory, the present study aimed to identify the presence of pulmonary regurgitation in patients with inferior wall AMI and to evaluate corresponding changes in Doppler flow patterns in relation to clinical findings.

Aims of the Study

1. To investigate Doppler-based indicators of physiological pulmonary regurgitation (PR) in patients presenting with right ventricular myocardial infarction (RVMI) in the context of acute inferior wall myocardial infarction (AMI).
2. To evaluate the prognostic value of Doppler-derived characteristics of physiological PR—specifically, a pressure half-time (PHT) of ≤ 150 ms and a minimum-to-maximum velocity ratio (Vmin/Vmax) of < 0.5—in predicting in-hospital complications among patients with acute inferior wall AMI.

MATERIALS AND METHODS

Study Design

The present study was a prospective study conducted in the Department of Cardiology, Coimbatore Medical College for a period of 6 months. Informed written consent was obtained from all patients before the start of the study. Institutional Ethics Committee approval was obtained.

Study Population

A total of 150 consecutive patients admitted with acute inferior wall ST elevation MI in the coronary care unit are included as study population for 6 months from May 2024. Among 150 patients, 26 patients were excluded as they did not fulfill the criteria to be included.

Inclusion Criteria

1. Documented presence of physiological pulmonary regurgitation (PR).
2. History of chest pain lasting longer than 30 minutes.
3. Electrocardiographic findings showing ST-segment elevation of ≥1 mm in at least two inferior leads (II, III, and aVF).
4. Positive cardiac biomarkers, including creatine kinase-MB (CK-MB) or troponin-T.
5. Sinus rhythm observed during the echocardiographic examination.

Exclusion Criteria

1. Either no pulmonary regurgitation or it's severe
2. Presence of pulmonary hypertension.
3. Patient refuses to undergo angiography
4. Has a known allergy to contrast material

Methods

All the patients underwent a detailed history taking, physical examination, electrocardiogram, and biochemical investigations. Patients who were eligible for reperfusion were treated with streptokinase.

Echocardiographic Examination

Two-dimensional and Doppler echocardiographic evaluations were performed on all patients using the GE VERSANNA ACTIVE echocardiography system. The probe was positioned in the left parasternal region to obtain a short-axis view. Color Doppler imaging was used to detect physiological pulmonary regurgitation (PR), and continuous wave Doppler was employed across the PR jet, showing a forward flow pattern during normal breathing.

The measured variables included

- Peak velocity of the PR jet (Vmax)
- Minimum velocity in mid-diastole just before the A wave (Vmin)
- Pressure half-time (PHT) of the PR
- The ratio of Vmax to Vmin was calculated (Vmax/Vmin).
- Additional parameters assessed included:
- Right ventricular (RV) size and dilatation in the apical four-chamber view
- RV wall thickness
- Left ventricular (LV) diameter
- LV and RV ejection fractions
- RV fractional area change
- Tricuspid annular plane systolic excursion (TAPSE)
- RV myocardial performance index (MPI)
- Tricuspid annular peak systolic velocity (s')

The tricuspid valve was examined in the apical four-chamber view, and any tricuspid regurgitation was assessed and graded using color Doppler. The inferior vena cava (IVC) diameter was measured during both inspiration and expiration using the subcostal view.

ISSN (O): 2687-5365; ISSN (P): 2753-6556

ECG Data

Right precordial lead V4R and posterior chest leads were recorded in all patients. Right ventricular involvement was considered when the electrocardiogram showed ST elevation of ≥1 mm in lead V4R. Similarly, posterior wall myocardial infarction was suspected when ST elevation of the same degree was observed in the posterior leads.

Cardiac Catheterization

Coronary angiography is performed in all patients during the period of admission within 7 days to assess the extent of coronary artery lesion. Significant coronary artery disease in a vessel is defined as the presence of significant (≥50%) stenosis on a main branch of the coronary angiogram. Patients are classified as having 1, 2, or 3 vessel disease according to the presence of lesions.

In-hospital Events

The short-term prognostic significance of right ventricular (RV) involvement, as identified by ECG findings and criteria, was assessed based on the occurrence of the following clinical events:

1. Mortality
2. Severe arrhythmias, including sustained ventricular tachycardia and ventricular fibrillation
3. Advanced atrioventricular (AV) block
4. Sinus node dysfunction
5. Requirement for temporary pacemaker insertion
6. Low cardiac output state, defined by systolic blood pressure below 90 mmHg

Statistical Analysis

Patients were categorized based on their Doppler flow characteristics, using a pressure half-time (PHT) of 150 ms as the cutoff. Those with a PR PHT ≤ 150 ms were assigned to Group 1, while those with PHT > 150 ms were assigned to Group 2. Differences between the groups were analyzed using the Chi-square test or Fisher's exact test for categorical variables. Continuous variables were presented as mean ± standard deviation. The Mann–Whitney U-test was employed for analyzing continuous data due to its robustness, especially with non-normal or skewed distributions, in comparison to the unpaired Student's t-test. Univariate analysis was conducted to identify predictors of in-hospital and 7-day outcomes. All statistical analyses were performed using SPSS software, version 17.0.

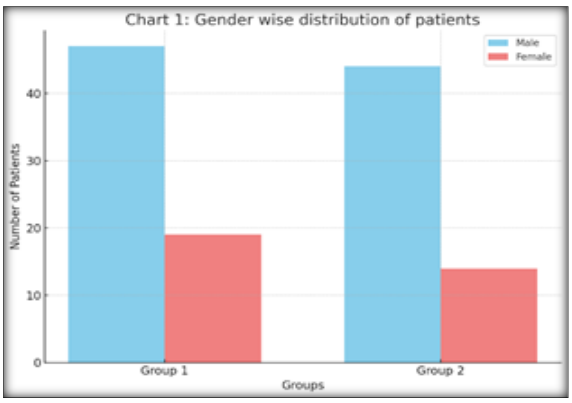

Figure 1: Gender wise distribution of patients

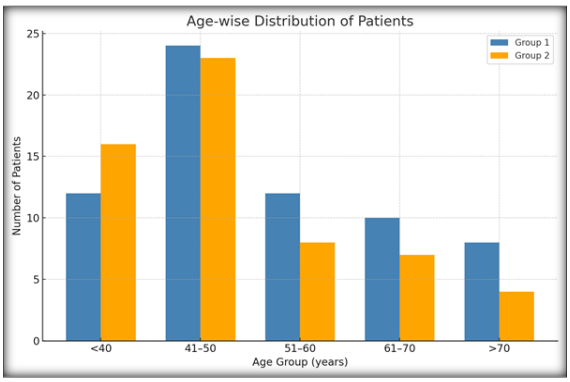

Figure 2: Age wise distribution of patients

Table 1: Gender wise distribution of patients in percentage

Gender	Group 1 (n=66)	%	Group 2 (n=58)	%	Total (n=124)	%
Male	47	71.2%	44	75.9%	91	73.4%
Female	19	28.8%	14	24.1%	33	26.6%

RESULTS AND DISCUSSION

A total of 124 patients were included in the study. Based on the pulmonary regurgitation (PR) pressure half-time (PHT), they were divided into two groups: Group 1 (PHT ≤ 150 ms) with 66 patients, and Group 2 (PHT > 150 ms) with 58 patients.

In Group 1, 70.4% were male, while 75.6% of Group 2 were male. The difference in sex distribution between the two groups was not statistically significant (P = 0.533). Gender data is presented in Table 1 and illustrated in Chart 1.

The mean age was 53.4 years in Group 1 and 54.5 years in Group 2. Among the 28 patients under 40 years of age, 12 belonged to Group 1. Patients over 75 years were considered high-risk for in-hospital and follow-up complications. However, age distribution between the two groups showed no statistically significant difference (P = 0.625), as shown in Figure 2.

Patients presented to the coronary care unit (CCU) with varying durations of chest pain. Ten patients reported chest pain lasting less than 2 hours, with the shortest being 1 hour. Sixty-eight patients arrived within 6 hours of symptom onset, while 16 presented more than 24 hours after onset. The average duration of chest pain was 8.4 hours in Group 1 and 12.5 hours in Group 2, though this difference was not statistically significant (P = 0.339).

Regarding cardiovascular risk factors

- Diabetes was present in 33.2% of Group 1 and 30.8% of Group 2 (not significant).

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- Hypertension was observed in 31 patients (31.8%) in Group 1 and 27 patients (36.5%) in Group 2.
- Smoking history was noted in 36.4% of Group 1 and 29.8% of Group 2 patients.

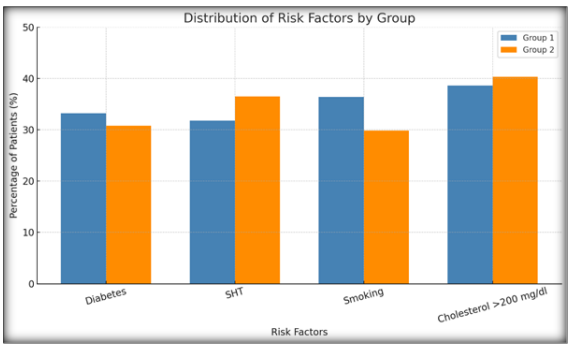

Figure 3: Risk factors among study population

In Group 1, 38.6% of patients had serum cholesterol levels >200 mg/dL, compared to 40.3% in Group 2. Analysis of individual cardiovascular risk factors between the two groups revealed no statistically significant differences (P > 0.05).

Regarding thrombolysis, 53 out of 66 patients in Group 1 (80.3%) and 46 out of 58 patients in Group 2 (77.5%) received thrombolytic therapy. Overall, 99 patients (79.8% of the total study population) were thrombolyzed. The difference in thrombolysis rates between the two groups was not statistically significant (P = 0.910).

Electrocardiographic analysis showed ST segment elevation ≥1 mm in lead V4R in 98.3% of patients in Group 1. Only two patients in Group 1 did not exhibit this finding. In contrast, only two patients in Group 2 demonstrated ST elevation in V4R. This difference between groups was statistically significant (P < 0.0001).

Posterior wall myocardial infarction, identified by ST elevation ≥1 mm in posterior leads (e.g., V9), was observed in 26 patients in Group 1 and 18 in Group 2—a difference that was not statistically significant. Similarly, ST elevation in lead V6, indicating possible lateral wall involvement, was found in five patients in Group 2 and two in Group 1, which was also not statistically significant.

Echocardiographic parameters were as follows:

- **RV wall thickness**: Mean of 2.94 mm in Group 1 and 2.96 mm in Group 2
- **RV dimension**: 37.2 mm in Group 1 vs. 26.3 mm in Group 2
- **LV end-diastolic dimension**: 37.4 mm in Group 1 and 39.1 mm in Group 2
- **LV ejection fraction**: No significant difference between groups

Right ventricular function parameters:

- **RV/LV ratio**: Mean of 1.03 in Group 1 and 0.70 in Group 2
- **RV fractional area change (FAC)**: 26.8% in Group 1 vs. 41.7% in Group 2
- **RV ejection fraction**: 33.4% in Group 1 and 46.1% in Group 2
- **Tricuspid annular plane systolic excursion (TAPSE)**: 12.4 mm in Group 1 and 18.7 mm in Group 2
- **Tissue Doppler-derived tricuspid annular systolic velocity (S' or TASV)**: 7.8 cm/s in Group 1 and 14.4 cm/s in Group 2
- **RV myocardial performance index (Tei index)**: 0.48 in Group 1 and 0.31 in Group 2

These measurements suggest notable differences in RV function between the groups.

Table 2: Various echo parameters of study population

Parameter	Units	Group 1 (Mean ± SD)	Group 2 (Mean ± SD)	P value
RV wall thickness	mm	2.94 ± 0.80	2.96 ± 0.88	0.747
RV dimension	mm	37.2 ± 5.14	26.30 ± 3.47	<0.0001
LVID (diastole)	mm	37.41 ± 5.20	39.10 ± 4.56	0.096
LV EF	%	54.98 ± 6.16	54.07 ± 12.46	0.169
RV/LV ratio	Ratio	1.03 ± 0.07	0.70 ± 0.11	<0.0001
RV FAC	%	26.80 ± 5.28	41.72 ± 7.84	<0.0001
RV EF	%	33.14 ± 4.36	46.12 ± 6.14	<0.0001
TAPSE	mm	12.40 ± 3.36	18.79 ± 3.76	<0.0001
TASV (S′)	cm/s	7.81 ± 2.52	14.44 ± 3.58	<0.0001
RV MPI (Tei index)	—	0.48 ± 0.08	0.31 ± 0.12	<0.0001
IVC diameter (inspiration	mm	8.28 ± 2.72	8.74 ± 3.14	0.318
IVC diameter (expiration	mm	19.64 ± 4.32	18.42 ± 4.22	0.034

Table 3: Pulmonary reurugitation echo parameters

Parameter	**Group 1 (Mean ± SD)**	**Group 2 (Mean ± SD)**	**P value**
Peak PR velocity (m/s)	1.43 ± 0.44	1.35 ± 0.30	0.334
End diastolic PR velocity(m/s)	0.76 ± 0.28	0.74 ± 0.28	0.764
Mid diastolic minimum(m/s)	0.42 ± 0.20	0.80 ± 0.34	<0.0001
Vmin/Vmax ratio	0.35 ± 0.18	0.72 ± 0.32	<0.0001
PHT of PR ms	100.4 ± 30.1	231.2 ± 56.4	<0.0001

ISSN (O): 2687-5365; ISSN (P): 2753-6556

Among the parameters analyzed, the following were found to be statistically significant between the two groups:

- Right ventricular (RV) dimension
- RV/LV ratio
- RV fractional area change (FAC)
- RV ejection fraction
- Tricuspid annular plane systolic excursion (TAPSE)
- Mitral annular systolic velocity
- RV Tei index (myocardial performance index)

All other parameters did not show statistically significant differences.

Pulmonary Regurgitation (PR) Doppler Characteristics

- Peak PR velocity and end-diastolic PR velocity did not differ significantly between Group 1 and Group 2.
- Mid-diastolic minimum PR velocity was significantly different, with a mean of 0.35 m/s in Group 1 and 0.68 m/s in Group 2 ($P < 0.0001$).
- Mean PR pressure half-time (PHT) was 101.2 ms in Group 1 and 226 ms in Group 2, as expected based on grouping.

Tricuspid Regurgitation (TR) and PR Severity

- TR was present in 34.0% of Group 1 and 18.0% of Group 2. This difference was not statistically significant ($P = 0.156$).
- Severe TR was noted in 5 patients (7.57%) in Group 1, while none in Group 2 had severe TR. However, this difference also did not reach statistical significance.

Regarding PR severity, moderate PR was observed in 5 patients in Group 1 and 2 patients in Group 2. This difference was also not statistically significant.

Table 4: TR and PR severity by ECHO

Parameter	Group 1Number of Patients	Group 1Percentage (%)	Group 2Number of Patients	Group 2Percentage (%)	P value
TR present	22	36.40	10	18.10	0.156
TR Severity					
Trivial	5	7.57	5	8.60	0.994
Mild	10	15.00	4	6.80	0.561
Moderate	2	3.03	1	1.70	0.576
Severe	5	7.57	0	0.00	0.200
PR Severity					
Trivial	25	37.87	24	41.31	0.693
Mild	36	54.54	33	56.89	0.940
Moderate	5	7.57	1	1.70	0.797
Severe	0	–	0	–	–

In-Hospital Outcomes and Prognostic Indicators

Out of 124 patients, 53 (42.7%) experienced in-hospital complications. The incidence was significantly higher in Group 1 (PHT ≤ 150 ms), where 55.8% developed complications, compared to 27.4% in Group 2 ($P = 0.012$).

Among complications:

- Hypotension: Present in 19 patients
- Oliguria (reduced urine output): 6 patients
- Requirement for volume loading: 15 patients
- Cardiogenic shock: 12 patients
- Congestive cardiac failure (CCF): 7 patients

All these indicators of low cardiac output—except oliguria—showed statistically significant differences between the groups.

Mortality

Nine patients (7.25%) died during hospitalization—all from Group 1. This difference was statistically significant ($P = 0.043$). The primary causes of death were refractory hypotension and ventricular arrhythmias.

Heart Blocks:

Twelve patients in Group 1 developed advanced atrioventricular block, while none in Group 2 did. This was statistically significant ($P = 0.043$).

Arrhythmias:

Significant arrhythmias occurred in 7 patients (5 from Group 1 and 2 from Group 2), but the difference was not statistically significant ($P = 0.92$).

Temporary Pacemaker (TPM) Insertion: Ten patients required TPM, with 9 in Group 1 and 1 in Group 2. The difference approached but did not reach statistical significance ($P = 0.08$).

Other Clinical Events:

- Recurrent angina: 10 patients (12.4%), no significant group difference ($P = 0.84$)
- Reinfarction rate: 4.35% (4 from Group 1, 1 from Group 2; $P = 0.80$)
- Revascularization: Required in 11 patients (6 from Group 1), not statistically significant ($P = 0.73$)

Univariate Analysis of Predictors of In-Hospital Events

Significant predictors of in-hospital events included:

- Age > 65 years (*P = 0.052*)
- ST elevation in lead V4R (*P = 0.015*)
- Echocardiographic RV dilatation (*P = 0.021*)
- Doppler-based RV involvement (PR PHT ≤ 150 ms; *P = 0.020*)
- Combined Vmin/Vmax ≤ 0.5 and PR PHT ≤ 150 ms (*P = 0.045*)
- Triple vessel disease on angiography (*P < 0.0001*), with the highest relative risk (RR = 3.6, 95% CI: 1.2–9.9) for in-hospital complications

ISSN (O): 2687-5365; ISSN (P): 2753-6556

DISCUSSION

This study evaluated the prognostic implications of Doppler-derived pulmonary regurgitation (PR) parameters in patients with acute inferior wall myocardial infarction (IWMI). The non-invasive Doppler criteria used (PHT ≤ 150 ms and Vmin/Vmax ≤ 0.5), based on the work by Cohen et al. (1995), proved useful in detecting RV infarction (RVMI). Their original study reported 100% sensitivity and 91% specificity using these thresholds with invasive confirmation.

In our study, the same Doppler criteria successfully identified RV involvement and showed significant prognostic value, correlating with increased rates of complications and mortality in Group 1.

Our findings are also consistent with those of Bueno et al., who reported a 47% in-hospital fatality rate in patients with RVMI versus 10% in those without RV involvement. The most common cause of death was non-reversible cardiogenic shock. In our population, mortality was 7.25%, lower than the 19% reported by Zehender et al. for IWMI and 31% in IWMI with RVMI. This reduction may be due to earlier recognition, improved reperfusion strategies, and enhanced CCU care.

ST elevation in V4R, easily identifiable on bedside ECG, was a strong predictor of adverse outcomes. Our study showed that its presence had a statistically significant prognostic association for major in-hospital events (OR = 1.5, P = 0.015), unlike the Cohen study where this was not independently validated.

Among traditional cardiovascular risk factors, only age > 65 years demonstrated a significant association with in-hospital outcomes. Other factors such as smoking, diabetes, hypertension, and hypercholesterolemia were not significant in this cohort—likely due to the relatively small sample size, limiting statistical power.

Recent literature has emphasized the prognostic value of RV involvement as assessed by cardiac MRI post-STEMI. Our echocardiographic findings (e.g., RV dilatation, reduced TAPSE, and TASV) similarly underscore RV dysfunction as a key determinant of early clinical outcomes.

CONCLUSION

1. Pulmonary regurgitation (PR) Doppler tracings are valuable in predicting in-hospital complications in patients with inferior wall acute myocardial infarction (AMI).
   Specifically, PR pressure half-time (PHT) ≤ 150 ms and Vmin/Vmax ratio ≤ 0.5 were found to be strong predictors of adverse in-hospital events.
2. The Doppler-derived parameters—PHT ≤ 150 ms and Vmin/Vmax ≤ 0.5—also serve as reliable indicators of right ventricular (RV) involvement in the setting of inferior wall MI.
3. Low output syndrome is a common, specific, and clinically significant complication of RV infarction, often contributing to in-hospital morbidity and mortality.

Limitations of the study

1. **Small Sample Size:** The limited number of patients in the study may affect the generalizability of the results. Larger, multicenter clinical trials are necessary to validate and extend these findings to broader patient populations.
2. **Lack of Long-Term Follow-Up:** This study focused solely on in-hospital outcomes. Long-term prognostic implications could not be assessed due to the absence of follow-up data.
3. **Omission of Infarct-Related Artery Characteristics:** Important angiographic factors such as thrombus burden, lesion morphology, and TIMI flow grade were not evaluated, which may influence both RV involvement and clinical outcomes.
4. **Thrombolysis Effectiveness Not Considered:** The study did not differentiate between successful and failed thrombolysis, which may significantly impact prognosis and could confound the interpretation of results.
5. **Exclusion of Patients Without Physiological PR:** Patients without detectable pulmonary regurgitation were excluded, which may introduce selection bias and limit the applicability of Doppler-derived parameters to all IWMI patients.

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ISSN (O): 2687-5365; ISSN (P): 2753-6556

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ISSN (O): 2687-5365; ISSN (P): 2753-6556