Review of Contemporary Philosophy
ISSN: 1841-5261, e-ISSN: 2471-089X
Vol 23 (2), 2024
Pp 7743 - 7753

The Role of Echocardiography in the Detection of Subtle Right Ventricle Dysfunction in Inferior Myocardial Infarction after Successful Primary PCI

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Abstract

Background: Globally, coronary artery disease (CAD), is the primary cause of death. CAD claims the lives of more than seven million people annually, making up 12.8% of all fatalities.

A myocardial infarction with ST-segment elevation (STEMI) is the most serious form of CAD.

This research aimed to evaluate the effectiveness of echocardiography in the identification of concealed RV dysfunction within 30 minutes of initial percutaneous coronary intervention (PCI), In patients with inferior STEMI who do not show clinical or electrocardiographic signs of the right ventricle (RV) infarction.

Methodology: Eighty-nine individuals with inferior STEMI were included in this cross-sectional observational research. The research was conducted at Helwan University Hospital and El-Zaitoun Specialized Hospital from June 2022 to June 2023.

Results: We found that concealed RV systolic dysfunction in 35 patients (39%) of the studied group, the key echocardiographic parameters (Tricuspid Annular Plane Systolic Excursion, tissue Doppler S', RV fractional area change (RVFAC), left ventricular ejection fraction (LVEF), and RV speckle tracking) were significantly impaired in the RV systolic dysfunction group. RVFAC was the most accurate detector of RV systolic dysfunction. Also, male gender, older ages, diabetes mellitus, hypertension, higher body mass index, and longer door-to-balloon time were higher in patients with RV systolic dysfunction.

Conclusion: Concealed RV systolic dysfunction isn't uncommon in patients with inferior STEMI due to right coronary artery occlusion, about 39%. The current study highlighted RVFAC as the best echocardiographic test to elicit RV systolic dysfunction resulting from inferior wall STEMI.

Keywords: Echocardiography, Subtle RV dysfunction, Inferior Myocardial Infarction, Successful Primary PCI

Received: 04 October 2024 **Revised**: 23 November 2024 **Accepted**: 10 December 2024

Introduction:

Coronary artery disease (CAD) is the leading cause of death worldwide. Over seven million people die from CAD each year, accounting for 12.8% of all fatalities [1]. ST-elevation myocardial infarction (STEMI) is acknowledged as the most serious of the several forms of CAD. STEMI is characterized by symptoms indicative of myocardial ischemia, such as chest pain or discomfort, accompanied by increased troponin levels with STEMI on an electrocardiogram (ECG), which results from the complete blockage of a coronary artery [2].

Notably, the incidence of STEMI has shown a downward trend, with reports indicating a decrease in the incidence rate (per 100,000) from 121 in 1997 to 77 in 2005 [3].

The growing use of reperfusion treatments, such as primary percutaneous coronary intervention (PCI), advanced antithrombotic treatments, and improved secondary prevention measures have been linked to a decrease in the rates of acute and long-term mortality after STEMI, according to a recent study [4].

Primary PCI, which is defined as an urgent catheter-based intervention for STEMI conducted without prior fibrinolytic therapy, is regarded as the optimal reperfusion approach when executed promptly by a skilled medical team [5].

Although the right ventricle (RV) has not historically gotten as much attention as the left ventricle, a wealth of data suggests that the RV's size and function are crucial in predicting unfavorable outcomes in cardiovascular disorders [6].

The concept of ventricular interdependence describes how the dimensions, shape, and compliance of one ventricle can influence the corresponding characteristics of the other ventricle through direct mechanical interactions. Although this phenomenon is constantly there, it is more noticeable when loading circumstances vary, as they do during breathing or sudden changes in position. A major contributing component to the pathogenesis of RV dysfunction is ventricular interdependence [7].

The systolic ventricular interdependence is largely governed by the inter-ventricular septum. In this regard, the pericardium's influence appears to be comparatively minor when juxtaposed with its role in diastolic ventricular interdependence [8].

Acute myocardial infarction (AMI) initiates both immediate and prolonged compensatory responses, which can be viewed as mechanisms aimed at improving the filling and cardiac output of the left ventricle (LV) and RV [9].

The assessment of the RV can be conducted through a variety of imaging and functional methodologies, echocardiography is the most commonly employed technique in clinical practice for evaluating RV structure and function. This imaging modality is preferred due to its adaptability and ease of access. Furthermore, Doppler-derived measures of RV function, including the myocardial performance index and tricuspid annular isovolumic acceleration, are increasingly recognized as important indicators of RV performance [10].

Speckle tracking echocardiography (STE) serves as an effective echocardiographic method for assessing myocardial function, owing to its superior temporal and spatial resolution, excellent reproducibility among different observers, angel independence, and resilience to the heart's translational movements [11].

Patients and Methods

The goal of our study was to determine if echocardiography can detect concealed right ventricular dysfunction in individuals with inferior STEMI due to right coronary artery (RCA) occlusion, who do not show any clinical or electrocardiographic indications of RV infarction within 30 minutes following primary PCI. Informed consent was secured from all the participants, ensuring they receive comprehensive information regarding potential risks and benefits as well as their freedom to leave the study at any time without consequence.

The Helwan University Faculty of Medicine's ethics committee has given its clearance, with our research being reviewed and accepted under institutional review board number IRB:58-2022.

Inclusion Criteria: Participants must be over 18 years of age. Electrocardiographic results must indicate inferior STEMI defined as ≥0.1mv at inferior leads (II, III, and aVf). Primary PCI must have been successfully completed, defined as thrombolysis in myocardial infarction (TIMI) -III flow at the culprit artery at the end of the procedure. RCA is an infarction-related artery.

Exclusion Criteria were pregnancy, the presence of autoimmune disorders, pulmonary artery systolic pressure (PASP) of 40 mmHg , chronic lung disease, the existence of congenital heart diseases that can lead to RV overload such as ventricular atrial septal defects, significant pulmonary stenosis, an evident RV infarction on the ECG with leads V3R–V4R showing STEMI of 0.1 mV or above, clinical manifestations suggestive of RV infarction, such as hypotension, absence of lung rales with distended neck veins without alternative clear causes and the infarct-related artery wasn't the RCA.

Operational Design: Subjects underwent the following assessments at admission and subsequent follow-up:

Complete History Taking: Age, sex, and pre-existing medical conditions including hypertension, dyslipidemia, drug history, family history of premature CAD and special habits such as smoking, drug abuse, and alcohol use.

General and Local Examination: Vital signs include blood pressure, respiratory rate, temperature and heart rate. Patient's appearance, oxygen saturation, decubitus, jugular venous pressure and presence of basal rales. Local examination of the heart for heart sounds, additional heart sounds, murmurs and thrills.

Electrocardiography (ECG): A 12-lead ECG was recorded at admission and after PPCI including right-sided ECG (V3R to V6R).

Routine Labs: Complete blood count (CBC), lipid profile, cardiac enzymes (Creatine kinase (CK), creatine kinase-MB (CK-MB), and troponin), urea and creatinine levels were measured.

Diagnostic Coronary Angiography and Primary PCI: Procedures followed the latest European Society of Cardiology (ESC) guidelines for the management of acute coronary syndrome (ACS) [12]. Myocardial reperfusion assessment according to TIMI-flow grade was evaluated at baseline and after coronary angioplasty [13].The vascular access either trans-radial or trans-femoral access was according to operator preference. All the patients received 300mg of oral aspirin and either 180mg of ticagrelor or 600mg of clopidogrel according to the availability.

Routine conventional 2D-Echocardiography: Standard echocardiographic views, M-mode, LV tissue Doppler imaging and 2D images were acquired during breath hold and stored and offline analysis was performed for each case by two expert echocardiographers to minimize the operator influence.

Assessment of left ventricular ejection fraction

From apical views, with a focus on LV, we assessed the ejection fraction (EF) of the LV by the Simson method by tracing the LV endocardium at end-diastole and end-systole, then using the following formula, **EF= LVEDV-LVESV/LVEDV** [14].

Assessment of RV Systolic Function:

Tricuspid Annular Plane Systolic Excursion (TAPSE) with normal reference ≥ 1.7 cm, by crossing TV annulus at RV free wall by M-mode cursor [15]. Doppler Tissue index of the tricuspid annulus (DTI) with normal reference ≥ 10 cm/sec. by positioning the Doppler sample just above the TV annulus at the RV free wall [16]. RV fraction area change (FAC) with normal reference >35%. RV Focused apical 4 view, Trace RV area in diastole and systole (cm^2), FAC= End diastolic area of the RV – End systolic area of the RV / End diastolic area of RV [17]. Using speckle-tracking strain echocardiography, From the RV-focused apical view (>60 frames/s), systolic 2-dimensional longitudinal strain was measured to determine the peak systolic longitudinal strain of the RV-free wall; a typical RV longitudinal strain is more negative than -20% [18]. This comprehensive approach aims to evaluate and monitor the RV function and associate clinical parameters following inferior STEMI and primary PCI.

Results:

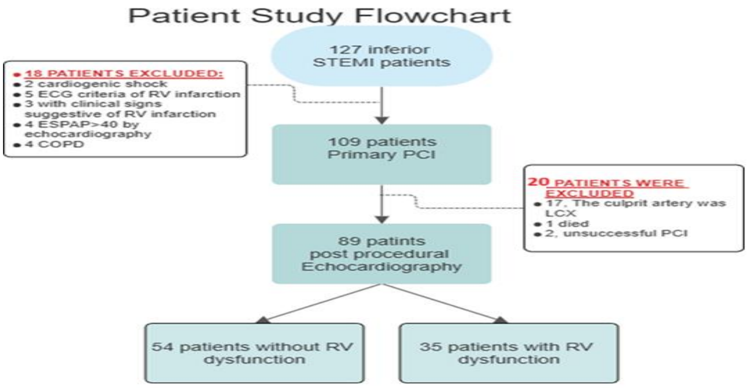

Figure 1: Flowchart of the studied group

After primary PCI, patients were divided into two groups according to RV systolic function parameters derived from post-intervention echocardiography, where 54 patients had normal RV systolic function parameters. In contrast, we found that 35 patients (39%) had echocardiographic parameters of concealed RV systolic dysfunction. **Figure 1 and 2**

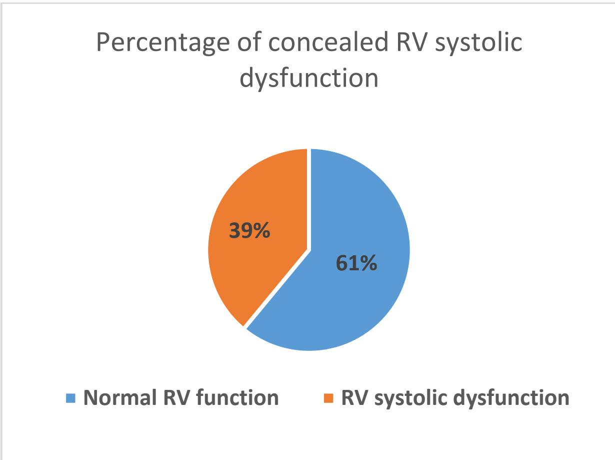

Figure (2) Percentage of concealed RV systolic dysfunction

The echocardiographic parameters of the studied groups are presented in **Table 1**

Table 1: Echocardiographic parameters among the studied patients

		N= 89
TAPSE (cm)		17.5 (12 – 25)
Tissue Doppler S` wave (cm/s)		10.84 ± 1.72
RV Speckle tracking		-17.24 ± 4.1
RVFAC		35 (24 – 50)
LVEF		54.92 ± 6.56
RV Systolic Function	**Normal**	54 (61.0%)
	Impaired	35 (39.0%)

Data are presented as mean ±SD or median (IQR). TAPSE: Tricuspid Annular Plane Systolic Excursion, RV: right ventricle, RVFAC: RV fractional area change, LVEF: Left ventricular ejection fraction.

Regards sex, IHD, family History of IHD and dyslipidemia there were insignificantly differences between both groups. While Age, BMI, DM prevalence, HTN prevalence and door-to-balloon time were significantly higher in the group with impaired RV systolic function than in the normal RV systolic function group (P<0.05). **Table 2**

Table 2: Comparison between both groups regarding demographic and PCI data

		RV Systolic Function		P-value
		Normal (n=54)	Impaired (n=35)	
Age (Years)		47.8 ± 12.8	55.52 ± 8.42	**0.015***
Sex	Female	13 (24.0%)	6 (16.0%)	0.480
	Male	41 (76.0%)	29 (84.0%)	
BMI (Kg/m²)		24.51 ± 5.22	30.01 ± 2.62	**0.000 ***
Risk factors	DM	11 (0.0%)	25 (70.0%)	**0.000***
	HTN	13 (24.0%)	22 (63.0%)	**0.000***
	IHD	02(0.037%)	4 (11.0%)	0. 2
	Family History of IHD	6 (11.1%)	5 (14.0%)	0.70
	Dyslipidemia	23 (42.6%)	19 (54.0%)	0.3
Door to balloon time	<90 mins	48 (88.9%)	10 (28.6%)	**0.000***
	>90 mins	6 (11.1%)	25 (71.4%)	

Data are presented as mean ±SD or frequency (%). * Significant p value <0.05, BMI: Body mass index, DM: diabetes mellitus, HTN: hypertension, IHD: ischemic heart disease, RV: right ventricle.

There was a significant negative correlation between the age and BMI of the patients studied and their RVFAC. **Tabe 3**

Table 3: Correlation of age and BMI with RVFAC

	Age		BMI	
	r	P-value	r	P-value
RVFAC	**-0.288***	**0.043**	**-0.600****	**0.000**

r: Pearson Coefficients, * Significant p value <0.05, BMI: Body mass index, RVFAC: RV fractional area change.

There was no significant relation between the patients' gender and RVFAC levels. Regarding patients' risk factors, there is a significant reduction in RVFAC levels among patients with DM compared to those without and in patients with HTN relative to normotensive patients. Additionally, individuals with a positive family history of ischemic heart disease demonstrated a statistically significant decline in RVFAC levels when compared to those with a negative family history. Moreover, patients with dyslipidemia showed a significant reduction in RVFAC levels compared to individuals with normal lipid profiles. Regarding procedural data, there was a significant decrease in RVFAC levels found in individuals who took more than 90 minutes door to balloon than in those who took less than 90 minutes. **Table 4**

Table 4: Relation of sex, risk factors of cad, and procedural data with RVFAC level

	Female (n=19)	Male (n=70)	Test value	P-value
RVFAC	42 (28 – 48)	33 (24 – 50)	-0.826≠	0.409
	No DM (n=53)	DM (n=36)	Test value	P-value

RVFAC	50 (44 – 56)	24 (20 – 28)	-6.076≠	**0.000***
	No HTN (n=54)	**HTN (n=35)**	**Test value**	**P-value**
RVFAC	52 (48 – 58)	26 (20 – 34)	-5.888≠	**0.000***
	Negative family history (n=78)	**Positive family history (n=11)**	**Test value**	**P-value**
RVFAC	52(48 – 58)	26(20 – 34)	-4.161≠	**0.000***
	No dyslipidemia (n=47)	**Dyslipidemia (n=42)**	**Test value**	**P-value**
RVFAC	54 (50 – 58)	27 (20 – 36)	-5.637≠	**0.000***
	Door-to -balloon time <90 mins (m=58)	**Door-to-balloon time >90 mins (n=31)**	**Test value**	**P-value**
RVFAC	46 (34 – 54)	20 (12 – 24)	-5.367≠	**0.000***

Data are presented as median (IQR). * Significant p value <0.05, DM: diabetes mellitus, HTN: hypertension, RVFAC: RV fractional area change.

Regards the parameters mentioned in **table 4**, we found LVEF ≤ 55 and BMI > 26 to be the most significant factors associated with RV dysfunction. **Table 5**

Table 5: Univariate and multivariate logistic regression analysis to assess predictors of RV dysfunction and age, BMI and LVEF among the studied patients

	Univariate				**Multivariate**			
	P-value	**OR**	**95% C.I. for OR**		**P-value**	**OR**	**95% C.I. for OR**	
			Lower	**Upper**			**Lower**	**Upper**
Age >43	**0.018***	13.500	1.556	117.137	–	–	–	–
BMI >26	**0.000***	29.571	5.466	159.970	**0.015***	19.51	1.799	211.542
LVEF ≤ 55	**0.000***	96.000	10.348	890.584	**0.001***	68.878	5.328	890.433

OR: Odds ratio, CI: Confident interval, * Significant p value <0.05, BMI: Body mass index, LVEF: Left ventricular ejection fraction, RV: right ventricle.

Thirty-days after discharge, there was no significant difference between the patients who presented with RV systolic dysfunction and those who presented with normal RV systolic function regarding RV systolic dysfunction, death, re-infarction, stroke, and more than grade 2 TR. **Table 6**

Table 6: Comparison after 30-days between patients with RV dysfunction and those without

	Patients with normal RVFAC (n=54)	**Patients with low RVFAC (n=35)**	**P value**
Abnormal RVFAC	0	2	0.3
Death	0	1	0.15
Re-infarction	0	0	
Stroke	0	0	

Data are presented as Frequency (%). RVFAC: RV fractional area change.

Discussion:

Following a myocardial infarction (MI), cardiac enlargement is a concerning symptom that is linked to noticeably worse survival. Lately, there has been a growing focus on restricting ventricular remodeling in order to enhance ventricular performance and improve therapeutic results [6]. Research on RV remodeling is limited, and the factors affecting RV dilation and dysfunction are not well understood. Because echocardiography is readily available and versatile, it continues to be the major technique for assessing RV anatomy and function. RV function may be evaluated with potential using Doppler-derived indicators such as the tricuspid annular isovolumic acceleration and the myocardial performance index. RVMI still has significant rates of morbidity and death even with improvements in outcomes with reperfusion therapies [19]. The current study aimed to assess the role of echocardiography in identifying subtle RV dysfunction in patients with inferior STEMI getting primary PCI without clinical or electrocardiographic signs of RV infarction within 30 minutes of PPCI. Eighty-nine patients with inferior STEMI who were admitted to the Cardiology department of El-Zaitoun Specialized Hospital and Helwan University Hospital's were included to achieve this goal. Regarding the incidence of RV systolic dysfunction, there was no discernible difference between males and females in the current research. In contrast, Obradovic et al. [20] reported that right ventricular infarctions occur more frequently in women than in men; 62.7% of women and 37.3% of men, had been diagnosed with right ventricular infarctions.

According to the current study, individuals with reduced RV systolic function had significantly higher BMIs and ages than normal patients. Given that aging is linked to alterations in arterial stiffness and is a key risk factor for atherosclerosis and decreased elasticity of the coronary blood vessels while higher BMI can contribute to atherosclerosis through factors like dyslipidemia and insulin resistance.

A higher BMI is linked to metabolic syndrome, which in turn is linked to CAD risk factors such as insulin resistance, dyslipidemia, hypertension, obesity and hypertension. Chronic inflammation and endothelial dysfunction are linked to aging and greater BMI, which impede blood vessel function and raise the risk of thrombus formation [21].

Individuals with reduced RV systolic function exhibited a markedly greater percentage of diabetes mellitus, hypertension, dyslipidemia and a family history of ischemic heart disease as compared to individuals with normal RV systolic function. The percentage of patients in the two groups who had previously had IHD did not, however, differ statistically significantly.

Prompt reperfusion through early PCI is crucial for preserving RV function and reducing complications. Delayed PCI, specifically door-to-balloon times greater than 90 minutes, is linked to worse RV systolic function and higher complication rates **[15]**.

Kidawa et al. [22] studied a cohort of seventy patients who had been diagnosed with RV MI. TAPSE and pulsed wave tissue Doppler echocardiography (TDE) were used to assess right ventricular function. Based on the amount of time that passed between the beginning of symptoms and percutaneous transluminal coronary angioplasty (PTCA), the participants were divided into two groups: group 1 (n = 25) had a duration of ≤3 hours, and group 2 (n = 45) had a length of >3 hours. Over a 30-day follow-up period, the researchers monitored adverse cardiac events, including mortality, cardiogenic shock, intra-aortic counter-pulsation, transvenous pacing assistance for a brief period, ventricular septal defect (VSD), cardiac tamponade and rupture of the free wall. The results showed that group 2 had a noticeably enhanced RVMPI whereas group 1 had a much higher TAPSE. In addition, individuals whose reperfusion was postponed for more than three hours saw a rise in cardiac events. When comparing individuals with impaired right ventricular systolic function to those with normal function, our study showed a substantial decrease in TAPSE, tissue Doppler S' wave, LVEF, and RVFAC, alongside a marked deterioration in right ventricular speckle tracking values in the former group. In a similar vein, the research by Demirci and Demirci [23] included 16 individuals who had inferior MI complicated by RVMI out of 46 patients who presented with inferior MI and received initial PCI. According to their findings, TAPSE readings were considerably lower in individuals with RVMI (1.39 ± 0.21 cm versus 2.35 ± 0.46 cm, $P < 0.001$). Consistent with our results, Mohamed et al. [6] found a strong relationship between the impairment of global and localized left ventricular systolic performance and the involvement of the RV. Moreover, El-Hadidy et al. [24] documented a noteworthy correlation between left ventricular systolic impairment and right ventricular dysfunction, also reported a significant association between right ventricular dysfunction and left ventricular systolic impairment.

The findings of our study align closely with those reported by Konishi et al. [25] found a strong relationship between longitudinal LV peak systolic strains and RV strains after looking at a group of 71 individuals who had previously experienced a MI.

Additionally, Antoni et al. [26] undertook research comprising 621 consecutive patients hospitalized with AMI who had echocardiographic examination within 48 hours of admission to measure left ventricular and RV function, and who received primary PCI.

Their results indicated that patients experiencing congestive heart failure exhibited significantly reduced TAPSE and RV strain. The RVFAC has emerged as the most reliable echocardiographic parameter for predicting RV systolic dysfunction. Notable observations include Age and BMI: A significant negative correlation exists between RVFAC and both age and BMI. No significant association was identified between RVFAC and sex. Patients with diabetes mellitus, hypertension, a positive family history of ischemic heart disease, and dyslipidemia demonstrated significantly lower RVFAC compared to those without these comorbid conditions. RVFAC values were significantly diminished in patients with a door-to-balloon time exceeding 90 minutes compared to those with a time of 90 minutes or less.

Conclusion

RVFAC is the most powerful echocardiographic detector of RV systolic dysfunction. Factors linked to RV dysfunction were LVEF ≤ 55% and BMI > 26 kg/m^2.

Recommendations

There is a pressing need for further prospective studies with larger sample sizes to accurately identify subtle right ventricular infarction through echocardiography in patients receiving primary PCI who had inferior STEMI.

Further investigation is also necessary to determine the risk variables linked to these disorders and to investigate the prognostic implications of concealed right ventricular infarction in this patient population.

Acknowledgement

I thank all the staff of the Cardiology Department Helwan University Hospital and EL-Zaitoun Specialized Hospital for their cooperation and kind support throughout my research period.

Authors' contributions

AhS performed the cardiac examination, history taking, ECG interpretation, Echocardiography assessment and interpretation. All authors performed the study design, writing the manuscript, statistical analysis and interpretation. All authors read and approved the final manuscript.

Funding

None.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The current study got approval of Faculty of Medicine, Helwan University ethical committee (IRB:58-2022) were obtained. Verbal consent was obtained from the enrolled subjects.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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List of Abbreviation:

CAD: Coronary artery disease

STEMI: ST-segment elevation

PCI: Percutaneous coronary intervention

RV: Right ventricle

RVFAC: Right ventricle fractional area change

LVEF: Left ventricular ejection fraction

RCA: right coronary artery

AMI: Acute myocardial infarction

STE: Speckle tracking echocardiography

PASP: Pulmonary artery systolic pressure

ESC: European Society of Cardiology

ACS: Acute coronary syndrome

TIMI: Thrombolysis in myocardial infarction

RVMPI: Right ventricular myocardial performance index

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