



# Subtle Right Ventricular Affection in Patients with Acute Myocardial Infarction, Echocardiographic Assessment

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## Abstract

**BACKGROUND:** The right ventricle (RV) has historically received less attention than its counterpart of the left side of the heart, yet there is a substantial body of evidence showing that RV size and function are perhaps equally important in predicting adverse outcomes in cardiovascular diseases.

**AIM:** The aim of our work was to evaluate incidence and impact of right ventricular (RV) affection in patients with acute left ventricular myocardial infarction subjected to primary percutaneous coronary intervention (1<sup>st</sup> PCI).

**METHODS:** The study was conducted on 80 patients who had acute left ventricle ST elevated myocardial infarction (LV STEMI) and subjected to 1<sup>st</sup> PCI. The study was done in Cairo University, critical care department. All patients were studied within 2 days after 1<sup>st</sup> PCI, RV function was assessed by echocardiography through tricuspid annular plane systolic excursion (TAPSE) and speckle tracking echocardiography. We excluded patients with RV infarction, moderate to severe tricuspid regurgitation, pulmonary hypertension, dilated cardiomyopathy, atrial or ventricular septal defect, and patients who had cardiac dysrhythmias.

**RESULTS:** Out of 80 patients (64 men and 16 women) included in the study, 38 patients (47.5%) had TAPSE <1.7 cm, and 48 patients (60%) had RV longitudinal strain less negative than -19%. There was a statistically significant relationship between RV affection and anterior STEMI, left anterior descending artery as an infarct-related artery, duration of intensive care unit stay, impairment of LV global and regional systolic function, in-hospital complications, and 1-year mortality.

**CONCLUSION:** RV dysfunction is not uncommon in acute LV STEMI when using the definition of TAPSE <17 cm and RV longitudinal strain less negative than -19%. There was a significant relationship between RV dysfunction and poor outcome in patients with acute LV STEMI.

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## Introduction

The right ventricle (RV) has historically received less attention than its counterpart of the left side of the heart, yet there is a substantial body of evidence showing that RV size and function are perhaps equally important in predicting adverse outcomes in cardiovascular disease [1].

Ventricular interdependence refers to the concept that the size, shape, and compliance of one ventricle may affect the size, shape, and pressure-volume relationship of the other ventricle through direct mechanical interactions. Although always present, ventricular interdependence is most apparent with changes in loading conditions such as those seen with respiration or sudden postural changes. Ventricular interdependence plays an essential part in the pathophysiology of RV dysfunction [1]. Systolic ventricular interdependence is mediated mainly through the interventricular septum. The pericardium may not be as important for systolic ventricular interdependence as it is for diastolic ventricular interdependence.

Acute myocardial infarction (AMI) is associated with early and late compensatory mechanisms which can

be seen as attempts to optimize ventricular filling and cardiac output of both the left ventricle (LV) and RVs [2].

Cardiac enlargement after a myocardial infarction (MI) is an ominous finding that is associated with distinctly reduced survival. Recently, interest has developed in limiting ventricular remodeling, with the objective of improving ventricular function and clinical outcome [3]. However, studies concerning RV remodeling are few and the extent, time, and causes for RV dilatation and dysfunction remain unclear.

The RV can be studied with many imaging and functional modalities. In clinical practice, echocardiography is the mainstay of evaluation of RV structure and function. Compared with other modalities, it offers the advantages of versatility and availability. Furthermore, Doppler-derived indices of RV function, such as the myocardial performance index and tricuspid annular isovolumic acceleration, are emerging as promising parameters of RV function [4].

No single method can give us all information and reliability about the RV; however, if some were done collectively with clinical history and examination, this will be better and more evident.

## Methods

The study was done on 80 patients who had acute left ventricle ST elevated myocardial infarction (LV STEMI) and subjected to primary percutaneous coronary intervention (1<sup>st</sup> PCI). The study was done in Cairo University, critical care department. All patients were studied within 2 days after 1<sup>st</sup> PCI.

We excluded all patients with:

1. RV infarction.
2. Moderate to severe tricuspid regurgitation.
3. Pulmonary hypertension; PH was defined as an estimated pulmonary artery systolic pressure (PASP)  $\geq 40$  mmHg [5].
4. Chronic pulmonary disease.
5. Dilated cardiomyopathy.
6. Atrial septal defect and ventricular septal defect.
7. Cardiac dysrhythmias.

Medical history and detailed physical examination were done for all patients. Routine laboratory tests, including cardiac enzymes, were obtained.

## Echocardiography

The routine formal study was done with the assessment of: Right ventricular (RV) systolic function using: Tricuspid annular plane systolic excursion (TAPSE), the normal reference limits being a TAPSE of  $\geq 1.7$  cm [6].

Peak systolic longitudinal strain of the RV free wall using speckle-tracking strain echocardiography, RV longitudinal strain of magnitude less negative than  $-20\%$  is likely abnormal [7].

Left ventricular peak systolic strains in the longitudinal direction using speckle-tracking strain echocardiography, normal values for left strain measurement is  $-19.9 \pm 5.3\%$  for longitudinal strain [8].

Estimated peak systolic pulmonary artery pressure (PH) was defined as an estimated PASP  $\geq 40$  mmHg. Patients with pulmonary hypertension were excluded from the study.

The 17-segment regional wall motion scoring index (RWMSI) was calculated.

The study was conducted using an iE33 PHILIPS colored echocardiographic machine using a 3.5 MHz transducer (Figures 1 and 2).

Finally, we followed the course of the patient regarding the occurrence of in-hospital complications, duration of stay in the intensive care unit (ICU), in-hospital, 30-day, and 1-year mortality.

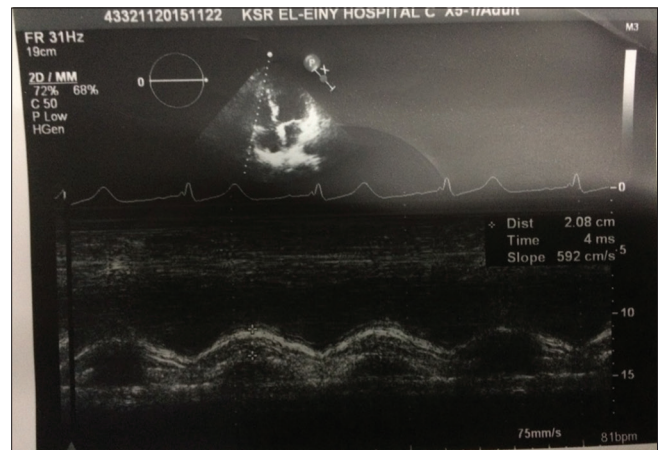


Figure 1: Tricuspid annular plane systolic excursion

## Statistical Analysis

Data were coded and entered using the Statistical Package for the Social Sciences version 24.

Data were arranged using mean, standard deviation, median, minimum, and maximum in quantitative data and using frequency (count) and relative frequency (percentage) for categorical data.

Comparisons between quantitative data were done using the Mann–Whitney test and for categorical data, Chi-square test was done. Exact test was used instead when the expected frequency is  $< 5$ .  $p < 0.05$  are statistically significant.

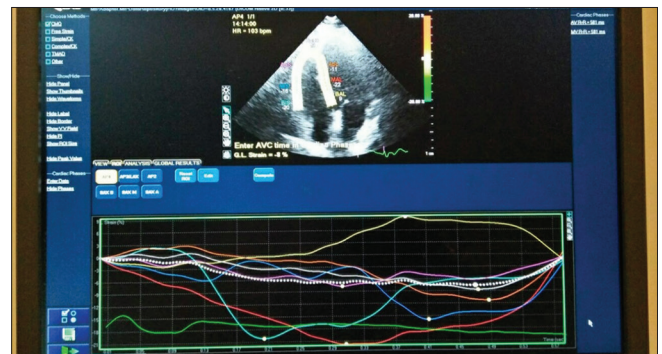


Figure 2: Right ventricular longitudinal strain by speckle tracking echocardiography

## Results

In our study, 80 patients (64 men and 16 women) aged 55 years admitted to ICU with acute STEMI and subjected with primary PCI.

In our study, risk factors are distributed as in (Table 1). The mean duration of ICU stay was  $6.4 \pm 2.5$  days (Table 2). During hospitalization, 28 (35%) patients developed in-hospital complications (cardiogenic shock, arrhythmias, and recurrent ischemia) while the

**Table 1: Risk factors**

Risk factors	Count	%
DM		
DM	34	42.5
Not diabetic	46	57.5
Hypertension		
Hypertensive	26	32.5
Normotensive	54	67.5
Smoking		
Smoker	64	80.0
Not smoker	16	20.0
Dyslipidemia		
Dyslipidemia	46	57.5
Normal	34	42.5
Ischemic heart disease (previous acute coronary syndrome)		
Positive history	16	20.0
No history	64	80.0
Family history		
Positive history	32	40.0
No history	48	60.0

**Table 2: Duration of intensive care unit stay**

Parameters	Mean	Standard deviation	Median	Minimum	Maximum
Intensive care unit stay (days)	6.4	2.5	6.00	3.00	18.00

rest of the patients had a smooth course (Table 3).

**Table 3: Incidence of in-hospital complications**

Parameters	Count	%
(In-hospital complications)	28	35.0

No documented in-hospital and 30-day mortality while on 1-year assessment, 4 mortalities were identified (Table 4).

**Table 4: The mortality**

Mortality	Count	%
In-hospital mortality		
Non-survivors	0	0.0
Survivors	80	100.0
30-day mortality		
Non-survivors	0	0
Survivors	80	100.0
1-year mortality		
Non-survivors	4	5.0
Survivors	76	95.0

### Coronary angiographic data

Infarct-related artery (IRA) was left anterior descending artery in 60 (75%) patients, right coronary artery in 16 (20%) patients, and left circumflex artery in only 4 (5%) patients. We found that thrombolysis in MI flow was 0 (pre PCI) and became II (post-PCI) in 18 (22.5%) patients and III (post-PCI) in 62(77.5%) patients (Table 5).

### Echocardiography data

The mean left ventricular end-diastolic diameter was  $62.53 \pm 30.42$  mm and the mean left ventricular end-systolic diameter was  $38.96 \pm 16.32$  mm. Left ventricular ejection fraction (LVEF) was

**Table 5: Coronary angiographic data**

Parameters	Count	%
Infarct related artery		
Left anterior descending artery	60	75
Left circumflex artery	4	5.0
Right coronary artery	16	20.0
Post percutaneous coronary intervention TIMI flow grade		
TIMI flow II	18	22.5%
TIMI flow III	62	77.5%

TIMI: Thrombolysis in myocardial infarction

$47.45\% \pm 10.44$  (Table 3). There were 46 (57.5%) patients with LV diastolic dysfunction Grade I and 34 (42.5%) patients with LV diastolic dysfunction Grade II. The 17-Segment Regional Wall Motion Scoring Index was calculated and the mean of our patients was  $1.51 \pm 0.25$  (Table 5).

Regarding the RV dimensions, we measured the RV mid-cavity dimension and the mean was  $2.43 \pm 0.25$  cm. The TAPSE of our patients was  $1.8 \pm 0.34$  cm (Table 5).

Regarding Speckle tracking echocardiography, we assessed the global longitudinal strains of the LV and RV using speckle tracking echocardiography, the mean LV longitudinal strain was  $-14.55 \pm 4.84\%$ , and the mean RV longitudinal strain was  $-15.7 \pm 5.06\%$  (Table 6).

**Table 6: Echocardiography parameters**

Parameters	Mean	Standard deviation	Median	Minimum	Maximum
LV end-diastolic diameter (mm)	62.53	30.42	50.20	40.40	135.00
LV end-systolic diameter (mm)	38.96	16.32	30.60	20.30	75.00
LV systolic function (EF %)	47.45	10.44	46.00	25.00	78.00
Regional wall motion scoring index	1.51	0.025	1.55	1.00	2.00
RV TAPSE	1.80	0.34	1.70	1.40	3.00
RV dimensions	2.43	0.25	2.45	1.70	2.90
LV longitudinal strain	-14.55	4.84	-13.50	-23.00	-8.00
RV longitudinal strain	-15.70	5.06	-15.00	-26.00	-8.00

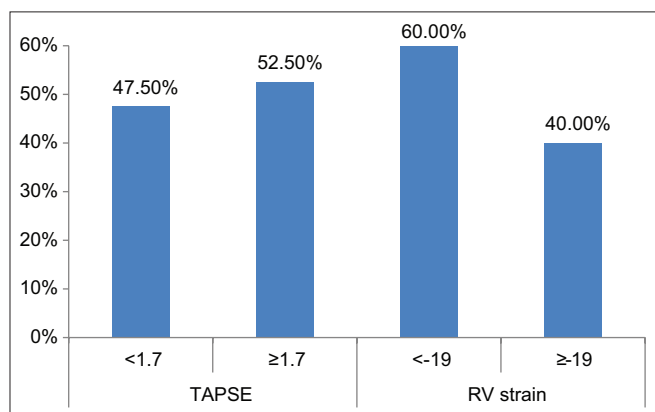
LV: Left ventricle, RV TAPSE: Right ventricle tricuspid annular plane systolic excursion, EF: Ejection fraction

On determining the incidence of RV dysfunction among these patients, we found that there were 38 (47.5%) patients with TAPSE  $<1.7$  cm and 48 (60%) patients with RV longitudinal strain less negative than  $-19\%$  (Table 7 and Figure 3).

**Table 7: Incidence of right ventricular dysfunction in patients with acute ST elevated myocardial infarction after 1<sup>st</sup> percutaneous coronary intervention (by echocardiography)**

Parameters	Count	%
Tricuspid annular plane systolic excursion		
$<1.7$	38	47.5
$\geq 1.7$	42	52.5
Right heart strain		
$<-19$	48	60.0
$\geq -19$	32	40.0

On studying the relationship between the site of MI and the RV affection, there was a statistically significant relationship between patients with anterior MI and RV dysfunction ( $p = 0.004$ ) (Table 8).



**Figure 3: Incidence of right ventricular dysfunction in patients with acute ST-elevation myocardial infarction after 1<sup>st</sup> percutaneous coronary intervention**

**Table 8: Right ventricular affection and site of MI**

Parameters	Site of MI (electrocardiogram)				p value
	Inferior		Anterior		
	Count	%	Count	%	
Tricuspid annular plane systolic excursion					
<1.7	4	20.0	34	56.7	0.004
≥1.7	16	80.0	26	43.3	
Right heart strain					
<-19	10	50.0	38	63.3	0.292
≥-19	10	50.0	22	36.7	

MI: Myocardial infarction

Furthermore, on studying the relationship between the IRA and the RV dysfunction, there was a statistically significant relationship between patients with IRA LAD and RV dysfunction ( $p = 0.009$ ) (Table 9).

**Table 9: Right ventricular affection and IRA**

Parameters	IRA						p value
	Left anterior descending artery		Left circumflex artery		Right coronary artery		
	Count	%	Count	%	Count	%	
Tricuspid annular plane systolic excursion							
<1.7	34	56.7	0	0	4	25.0	0.009
≥1.7	26	43.3	4	100.0	12	75.0	
Right heart strain							
<-19	38	63.3	0	0.0	10	62.5	0.054
≥-19	22	36.7	4	100.0	6	37.5	

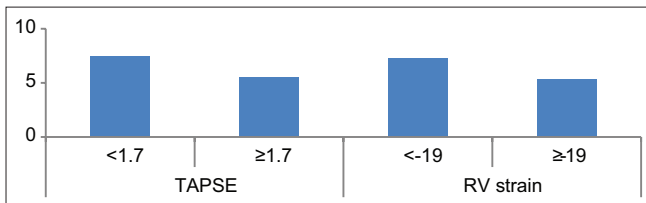
IRA: Infarct related artery

There was a significant statistical relationship between RT ventricular dysfunction (as assessed by TAPSE and RV longitudinal strain) and the duration of ICU stay, we observed that patients with RV dysfunction had a prolonged ICU stay,  $p < 0.001$  (Table 10 and Figure 4).

**Table 10: Right ventricular affection and duration of ICU stay**

Parameters	ICU stay (days)					p value
	Mean	Standard deviation	Median	Minimum	Maximum	
	Tricuspid annular plane systolic excursion					
<1.7	7.47	3.03	7.00	3.00	18.00	<0.001
≥1.7	5.52	1.54	5.00	3.00	9.00	
Right heart strain						
<-19	7.21	2.84	7.00	3.00	18.00	<0.001
≥-19	5.31	1.40	5.00	3.00	8.00	

ICU: Intensive care unit



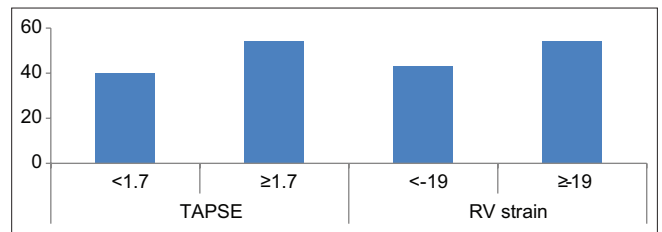
**Figure 4: Right ventricular affection and duration of intensive care unit stay**

It was found that RV dysfunction in our patients was related to the impairment of LV systolic function ( $p < 0.001$ ) (Table 11 and Figure 5) and to the RWMSI; the larger RWMSI value, the more RV affection ( $p < 0.001$ ) (Table 12).

**Table 11: Right ventricular affection and impairment of LV systolic function EF %**

Parameters	LV systolic function (EF %)					p value
	Mean	Standard deviation	Median	Minimum	Maximum	
	Tricuspid annular plane systolic excursion					
<1.7	40.21	6.15	41.00	25.00	47.00	<0.001
≥1.7	54.00	9.15	51.00	40.00	78.00	
Right heart strain						
<-19	42.96	8.77	42.50	25.00	64.00	<0.001
≥-19	54.19	9.22	51.00	45.00	78.00	

LV: Left ventricular, EF: Ejection fraction



**Figure 5: Right ventricular affection and impairment of left ventricular systolic function (ejection fraction %)**

**Table 12: Right ventricular affection and RWMSI**

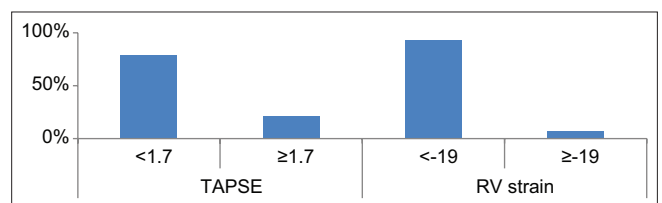
Parameters	RWMSI					p value
	Mean	Standard deviation	Median	Minimum	Maximum	
Tricuspid annular plane systolic excursion						
<1.7	1.70	0.14	1.70	1.47	2.00	<0.001
≥1.7	1.35	0.20	1.30	1.00	1.80	
Right heart strain						
<-19	1.63	0.22	1.70	1.20	2.00	<0.001
≥-19	1.35	0.19	1.35	1.00	1.64	

RWMSI: Regional wall motion scoring index

There was a statistically significant relationship between RT ventricular dysfunction and in-hospital complications ( $p < 0.001$ ) (Table 13 and Figure 6). Furthermore, there was a significant relationship between RV dysfunction and the 1-year mortality ( $p = 0.047$ ) (Table 14 and Figure 7).

**Table 13: Relation of right ventricular affection and in-hospital complications**

Parameters	(In-hospital complications)				p value
	Yes		No		
	Count	%	Count	%	
Tricuspid annular plane systolic excursion					
<1.7	22	78.5	16	30.7	<0.001
≥1.7	6	21.5	36	69.3	
Right heart strain					
<-19	26	92.9	22	42.3	<0.001
≥-19	2	7.1	30	57.7	



**Figure 6: Relation of right ventricular affection and occurrence of in-hospital complications**

There was a statistically significant correlation between RV longitudinal strain and RV-TAPSE as two echocardiographic methods for RV systolic function assessment ( $r = 0.792$  and  $p < 0.001$ ) (Table 15 and Figure 8).

**Table 14: Right ventricular affection and 1-year mortality**

Parameters	1-year mortality				p value
	Alive		Dead		
	Count	%	Count	%	
Tricuspid annular plane systolic excursion					
<1.7	34	44.7	4	100.0	0.047
≥1.7	42	55.3	0	0.0	
Right heart strain					
<-19	44	57.8	4	100.0	0.146
≥-19	32	42.2	0	0.0	



**Table 15: Cor relationship between RV longitudinal strain and RV-TAPSE as two methods for RV systolic function assessment**

Parameters	RV-TAPSE
RV longitudinal strain	
Correlation coefficient (r)	0.792
p value	<0.001
n	40

RV-TAPSE: Right ventricular-tricuspid annular plane systolic excursion

## Discussion

In 1616, Sir William Harvey was the first to describe the importance of RV function [1].

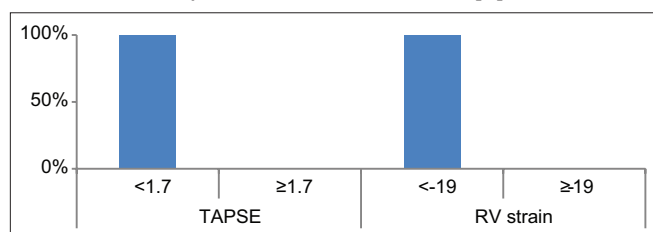


Figure 7: Right ventricular affection and 1-year mortality

The LV and RV are working as a “functional syncytium” and the two ventricles cannot be dissociated in an independent manner since the architecture of the distinct myocardial bands makes it mandatory for an integrated and unified function of both chambers.

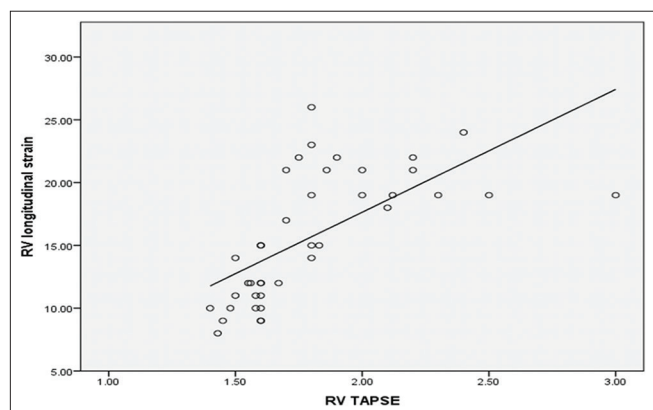


Figure 8: Correlation between right ventricular (RV) longitudinal strain and RV-tricuspid annular plane systolic excursion as two methods for RV systolic function assessment

TAPSE is frequently used measurement to assess RV function and reflects the longitudinal systolic excursion of the lateral tricuspid valve annulus. It is easily obtained and has been shown to have robust diagnostic and prognostic value in several disease states. The primary challenge and main limitation of fractional area change (FAC) is the accurate identification and tracing of the true RV endocardial border rather than the prominent trabeculations and muscle bands [9]. On the other side, TAPSE measurement is not dependent on either geometric assumptions or traceable endocardial edges.

Strain is a novel technique that enables the angle-independent measurement of active myocardial

deformation. Peak RV longitudinal strain, which quantifies the maximal shortening in the RV free wall from apex to base, is likely to be a good estimator of RV function because 80% of the stroke volume is generated by longitudinal shortening of the RV free wall [10].

In our study on determining the incidence of RV dysfunction among the patients with acute MI after 1<sup>st</sup> PCI, we found that there were 38 (47.5%) patients with TAPSE <1.7 cm and 48 (60%) patients with RV longitudinal strain less negative than -19%. Thomas *et al.* 2016 [11] conducted a prospective study to assess RV function in patients with acute MI treated with primary PCI. They found that there were (5.2%) of patients had reduced TAPSE, (32%) patients had RV free wall longitudinal strain (FWLS) <-20%, and 15 patients (11%) had RV FWLS <-15% within 1.6 (interquartile range 1.4–2.5) days after STEMI. Keren Shahar *et al.* in 2016 [12] studied 1044 patients with acute MI. RV systolic function was assessed qualitatively by integrating visual assessment of the contractility of the RV walls from different views and quantitatively by calculating the RV FAC. Patients were classified into 4 groups according to the presence or absence of RV dysfunction and pulmonary hypertension; normal RV without pulmonary hypertension (n = 509), normal RV and pulmonary hypertension (n = 373), RV dysfunction without pulmonary hypertension (n = 64), and RV dysfunction and pulmonary hypertension (n = 98).

On studying the relationship between the site of MI and the RV dysfunction, there was a statistically significant relationship between patients with anterior MI and RV dysfunction (p = 0.004). Furthermore, there was a statistically significant relationship between patients with IRA LAD and RV dysfunction (p = 0.009).

This disagrees with the results of Alam *et al.* in year 2000 [13], in which they prospectively compared the RV function between 38 patients with a first acute inferior MI, 33 patients with a first anterior MI, and 24 age-matched healthy individuals, they found that the peak systolic velocity of the tricuspid annulus was significantly reduced in inferior MI compared with that in healthy individuals (12 vs. 14.5 cm/s, p < 0.001) and patients with anterior MI (12 and 14.5 cm/s, p < 0.001). Patients with inferior MI were divided into two subgroups: Those with and those without electrocardiographic signs of RV infarction. The tricuspid annular motion was significantly lower in patients with RV infarction than in patients without RV infarction (17 and 22.7 mm, p < 0.001). This controversy may be due to the exclusion of patients with RV infarction from our study, while Alam *et al.* study [13] did not exclude them.

In our study, there was a statistically significant relationship between RT ventricular dysfunction and the duration of ICU stay, we observed that patients with

RV dysfunction had a prolonged ICU stay ( $p < 0.001$ ). Jensen *et al.* in year 2010 [14] conducted a study on 50 patients admitted with STEMI, they assessed RT ventricular involvement by cardiac MRI and conducted that duration of ICU treatment was longer with the group of RV involvement than those without RV involvement did not differ significantly between the group with and that without RV involvement ( $3 \pm 0.9$ ,  $2.7 \pm 0.9$  days, respectively,  $p = 0.3$ ).

It was found in our results that RV dysfunction was related to the impairment of LV systolic function, and the relation was statistically significant ( $p < 0.001$ ). This agreed with the study done by Antoni *et al.* 2010 [15], in which 621 consecutive patients admitted with AMI treated with primary PCI underwent echocardiography within 48 h of admission to assess left ventricular and RV function. Patients with congestive HF had significantly lower TAPSE ( $1.6 \pm 0.2$  cm vs.  $1.7 \pm 0.2$  cm,  $p = 0.01$ ) and RV strain ( $-19 \pm 6\%$  vs.  $-22 \pm 7\%$ ,  $p = 0.02$ ), also our results were similar to the results obtained by Konishi *et al.* 2013 [16], in which they proved a strong correlation relationship between RV strains and longitudinal LV peak systolic strains.

We observed in our study that RV affection was significantly related to the RWMSI, the larger RWMSI value, the more RV affection ( $p < 0.001$ ). This agreed with the results obtained from Keren Shahar *et al.*, study in year 2016 [12], in which RWMSI was significantly higher in patients with RV dysfunction than patients with normal RV function ( $p < 0.001$ ).

Our results revealed a significant statistical relationship between RV affection and in-hospital complications ( $p < 0.001$ ) and 1 year mortality,  $p = 0.047$ . This agreed with the study of Zornoff *et al.* They did a sub-study in year 2002 [17], in which two-dimensional echocardiograms were obtained in 416 patients with LV dysfunction (LVEF  $<$  or  $= 40\%$ ) from the survival and ventricular enlargement echocardiographic study (mean  $11.1 \pm 3.2$  days post-infarction). RV function assessed by the FAC was related to clinical outcome. They concluded that RV function is an independent predictor of death and the development of HF in patients with LV dysfunction after MI. Antoni *et al.* in year 2010 [15] found that RV FAC, TAPSE, and RV strain were all univariable predictors of worse outcomes in patients treated with primary PCI for AMI.

In our study, there was a statistically significant correlation between RV longitudinal strain and RV-TAPSE as two echocardiographic methods for RV systolic function assessment ( $r = 0.792$  and  $p < 0.001$ ), which agreed with the study of Kanar *et al.* 2017 [18], in which they assessed the effect of RV on early mortality in 81 patients with inferior MI, it is worth noting that ROC analysis showed similar sensitivity and specificity values for RV strain and TAPSE in predicting early mortality in their study.

## Conclusion

RV dysfunction is not uncommon in acute LV STEMI when using the definition of TAPSE  $< 17$  cm and RV longitudinal strain less negative than  $-19\%$ .

There was a significant relationship between RV dysfunction and poor outcome in patients with acute LV STEMI.

Application of speckle-tracking echocardiography to conventional measurements of RT ventricular function by TAPSE could provide a more thorough and quantitative pathophysiological characterization of functional RV adaptation following MI.

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