FULL LENGTH ARTICLE

Right ventricular echocardiographic parameters for prediction of proximal right coronary artery lesion in patients with inferior wall myocardial infarction

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Background: Classifying the location of an occlusion in the culprit artery during ST-elevation myocardial infarction is important for risk stratification to optimize treatment.

Objectives: To compare the validity of echocardiographic parameters assessing right ventricular (RV) function for the prediction of proximal right coronary artery (RCA) lesion in patients with inferior wall myocardial infarction.

Methods: The study included 76 patients after their first episode of acute inferior myocardial infarction with significant RCA lesion (43 patients with proximal RCA stenosis and 33 patients with distal RCA stenosis). Full echocardiographic examination was done before revascularization, including RV dimension, tricuspid annular plane systolic excursion, and tissue Doppler imaging of RV free wall at the level of the tricuspid annulus and recording the following variables: peak systolic velocity (Sm), peak early diastolic velocity, peak late diastolic velocity, ejection time (ET), isovolumetric relaxation time (IVRT), isovolumetric contraction time (IVCT), and myocardial performance index (MPI), which was calculated as (MPI = IVRT + IVCT/ET).

Results: Patients with proximal RCA showed significantly lower Sm (10.44 ± 2.61 cm/s vs. 12.11 ± 2.94 cm/s, $p = 0.013$) and shorter ET (224.18 ± 49.96 ms vs. 280.90 ± 46.12 ms, $p = 0.001$). While IVRT, IVCT, and MPI were significantly higher (95.25 ± 19.22 ms vs. 68.48 ± 12.77 ms, $p = 0.001$; 81.62 ± 23.59 ms vs. 60.90 ± 17.38 ms, $p = 0.001$; and 0.82 ± 0.222 vs. 0.47 ± 0.10, $p = 0.001$, respectively) when compared with patients with distal RCA stenosis. Multiple regression analysis including (tricuspid annular plane systolic excursion, Sm, and MPI) showed that the most independent predictors for proximal RCA lesions were MPI ($p = 0.0001$). The receiver operator characteristic curve for MPI showed areas under the curve of 97% and a confidence interval of 93%. A cut-off value of 0.58 for MPI had a sensitivity of 95% and specificity of 97% for the diagnosis proximal RCA.

Conclusions: The most independent predictors for proximal RCA lesion is MPI.

Keywords: Echocardiography, Right coronary artery

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Introduction

In patients with acute inferior wall myocardial infarction (IWMI), the infarct related artery could be the right coronary artery (RCA) or left circumflex artery [1].

Acute occlusion of the RCA proximal to the right ventricular branches may result in right ventricle infarction (RVI) [2–6]. This identifies a significant subgroup of patients that are associated with considerable immediate morbidity and mortality [7–11].

The diagnosis of acute ST-elevation IWMI depends mainly on specific electrocardiographic (ECG) criteria. Predicting the culprit artery in IWMI has been proposed using multiple ECG algorithms, with adequate sensitivity only in patients with extensive ST-segment deviation [12,13].

There are only limited studies validating the usefulness of various echocardiographic parameters of RV function in predicting proximal RCA stenosis. Most of them assessed only a single parameter of RV function and many lacked angiographic correlation [14]. Moreover, there are no available data comparing these parameters in predicting proximal RCA stenosis.

Objectives

To compare the validity of different echocardiographic parameters assessing RV function for prediction of proximal RCA stenosis in patients with inferior wall MI.

Patients

We screened 88 patients who were referred to King Abdulla Medical City with acute IWMI for coronary angiography and possible percutaneous coronary intervention during the period from October 2012 to February 2014. According to our inclusion criteria we enrolled 76 nonconsecutive patients (57 men and 19 women with a mean age of 58.84 ± 12.78 years) Inclusion criteria:

1. Significant RCA lesion at coronary angiography.
2. Good echocardiographic window.

Exclusion criteria:

1. Patients who were candidates for primary percutaneous coronary intervention or patients with hemodynamic instability.
2. Patients with significant left anterior descending, left circumflex artery lesion, diffuse RCA lesion, or multi-vessels disease.
3. Poor echo window.
4. Patients with previous MI, cor-pulmonale, atrial fibrillation, or significant valvular lesion.

Abbreviations

TAPS	Etricuspid annular plane systolic excursion
TDI	Itissue Doppler imaging
Sm	peak systolic velocity
Em	peak early diastolic velocity
Am	peak late diastolic velocity
ET	ejection time
IVRT	isovolumetric relaxation time
IVCT	isovolumetric contraction time
MPI	myocardial performance index
IWMI	inferior wall myocardial infarction
LAD	left anterior descending
LCX	left circumflex artery
RCA	right coronary artery
PCI	percutanous coronary intervention
RVF	right ventricular failure
RVSP	right ventricular systolic pressure
RVD	right ventricular dimension
ROC	receiver operator characteristic curve
CMR	cardiac magnetic resonance

According to angiographic findings, the patients divided into Group A included 43 patients with proximal RCA stenosis (34 men and 9 women with a mean age of 56.88 ± 12.4 years) and Group B included 33 patients with distal RCA stenosis (23 men and 10 women with a mean age of 61.39 ± 12.8 years).

All patients gave informed consent, and ethical approval was obtained from the Internal Review Board at our institution.

Methods

Clinical evaluation

For detection of right ventricular failure (RVF) defined as hypotension and elevated jugular venous pulse in the presence of clear lung fields [15].

ECG

Twelve-lead ECG includingV3R and V4R were used for diagnosis of IWMI, arrhythmias (bradycardia, high-degree atrioventricular block, atrial fibrillation, and ventricular tachycardia), and right ventricular infarction which defined as ST-segment elevation of more than 0.1 mV in V3R and V4R in ECG taken within 6 hours of onset of symptoms [16].

Laboratory tests

Blood samples were taken for measurement of cardiac biomarkers (troponin I), lipid profile (total cholesterol, low density lipoprotein, high density lipoprotein, and triglycerides), and random blood sugar.

Transthoracic Echocardiography

Complete conventional (two dimensional, M-mode, and Doppler) echocardiographic examination was done before coronary angiography using iE33 ultrasound system (Philips Healthcare, USA), equipped with a fully sampled matrix transthoracic transducer (xMATREX, X5-1). Standard views were obtained in the left lateral supine position according to recommendations of the American Society of Echocardiography [17].

Conventional Echocardiography

Right ventricular systolic pressure (RVSP) was determined from peak tricuspid regurgitation (TR) jet velocity using the simplified Bernoulli equation and combining this value with an estimate of the RA pressure, which was estimated from inferior vena cava diameter and respiratory changes [18].

RV dimension was estimated at the end-diastole from a right ventricle-focused apical four-chamber view, demonstrating the maximum diameter of the RV, while the crux and apex of the heart are in the view [18].

RV function parameters

Tricuspid annular plane systolic excursion (TAPSE) was acquired by placing an M-mode cursor through the tricuspid lateral annulus in an apical four-chamber view and measuring the amount of longitudinal motion of the annulus at peak systole [18].

Pulsed tissue Doppler imaging

Images were obtained from an apical four-chamber window with a tissue Doppler mode and the region of interest highlighting the RV free wall. The pulsed Doppler sample volume was placed at the tricuspid annulus of the basal segment of the RV free wall (at the end of expiration to minimize translational motion); specific software then generates velocity profiles over the cardiac cycle as follows:

- One major positive peak systolic velocity as the annulus moves towards the apex during systole (Sm).
- One negative early diastolic myocardial velocity as the annulus ascends away from the apex (Em).
- Another negative late diastolic myocardial velocity (Am).
- The velocities profile of Sm, Em, and Am waves were recorded [18].
- Sm duration was measured as the ejection time (ET).
- The time between the end of the Sm and the beginning of the Em was measured as isovolumic relaxation time (IVRT).
- The time between the end of Am and the beginning of Sm was measured as isovolumic contraction time (IVCT).
- Myocardial performance index (MPI): The MPI is defined as the ratio of isovolumic times divided by ET. MPI = [(IVRT + IVCT)/ET] [18].

Coronary angiography was done within 1 week of admission:

- Significant stenosis was defined as 50% or greater coronary lumen stenosis, acute thrombosis, or dissected plaque.
- Proximal RCA lesion defined as RCA lesion before the origin of acute marginal branch.

Statistical analysis

STATA software version 11.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analyses. For descriptive purposes, categorical variables were presented as percentages, and numerical variables were presented as mean ± standard deviation or median and range, according to their distribution. Comparison between groups was done using Student *t* test or Mann–Whitney test (according to data distribution) for continuous variables and by Chi-square test for categorical variables. Multiple regression analysis was performed including parameters of RV function (TAPSE, Sm, MPI) to explore the parameters most useful for the prediction of proximal RCA ischemia. Receiver operator characteristic curve was constructed for the most independent predictors for proximal RCA lesions. Youdon's equation was used to determine the best cut-off value for the useful parameters to give equal weight to sensitivity and specificity.

Results

Our study population included 76 patients with significant RCA lesions (57 men and19 women with a mean age of 58.84 ± 12. 78 years) divided into Group A including 43 patients with proximal RCA stenosis (34 men and 9 women with a mean age of 56.88 ± 12.4 years) and Group B including 33 patients with distal RCA stenosis (23 men and10 women with a mean age of 61.39 ± 12.8 years).

Table 1. Patient characteristics.

	A (43 patients)	B (33patients)	*p* value
Age (years, mean ± SD)	56.88 ± 12.4	61.39 ± 12.8	0.12
Sex			
Men	34(79.1%)	23(69.7%)	0.35
Women	9(20.9%)	10(30.3%)	
DM (n, %)	24(55.8%)	19(57.6%)	0.87
HTN (n, %)	23(56.1%)	23 (69.6%)	0.16
Smoking (n, %)	32(74.4%)	23 (69.6%)	0.45
Cholesterol mg/dL (mean ± SD)	166.4 ± 43.18	165.7 ± 44.06	0.94
LDL mg/dL (mean ± SD)	108.71 ± 48.96	100.14 ± 32.98	0.39
HDL mg/dL (mean ± SD)	35.68 ± 9.93	38.71 ± 11.9	0.26
Triglyceride mg/dL (mean ± SD)	132.28 ± 72.35	145.78 ± 74.79	0.46
Tropnin I ng/mL (median, range)	6.05(0.98–118)	4.6(0.8–44)	0.03
SBP (mmHg, mean ± SD)	123.9 ± 17.64	125.59 ± 17.58	0.71
DBP (mmHg, mean ± SD)	72.35 ± 9.88	71.59 ± 13.51	0.80
HR (B/M, mean ± SD)	74.79 ± 15.68	73.39 ± 14.40	0.69
RVMI (n, %)	30 (69.7%)	6 (18.1%)	0.001
Thrombolytic therapy (n, %)	31(72%)	23(69.6%)	0.42
No thrombolytic therapy (n, %)	12(27.9%)	10(33.3%)	0.39
Arrhythmia (n, %)	11(25.6%)	5 (15.2%)	0.26
RVF (n, %)	5(11.6%)	2 (6.1%)	0.40
Cardiogenic shock (n, %)	3(7.0%)	1(3.0%)	0.4

DBP = diastolic blood pressure; DM = diabetes mellitus; HDL = high density lipoprotein; HR = heart rate; HTN = hypertension; LDL = low density lipoprotein; RVF = right ventricular failure; RVMI = right ventricular myocardial infarction; SBP = systolic blood pressure; SD = standard deviation.

The study group showed no significant difference in the incidence of ischemic heart disease risk factors, systolic blood pressure, diastolic blood pressure, or heart rate between patients with proximal RCA stenosis (Group A) and distal RCA stenosis (Group B). The incidence of RVMI was significantly higher in Group A (69.7% vs. 18.1%, $p = 0.2$) and troponin level was significantly higher in Group A (25.39 ± 47.83 ng/mL vs. 12.76 ± 33.48 ng/mL, $p = 0.03$). In Group A, the occurrence of arrhythmia (complete heart block or bradycardia) and RVF was numerically higher but not statistically significant when compared with Group B. Arrhythmia and RVF were 25.6% and 11.6% versus 15.2% and 6.1% in Groups A and B, respectively Table 1.

When compared with Group B, Group A showed significantly lower Sm (10.44 ± 2.61 cm/s vs. 12.11 ± 2.94 cm/s, $p = 0.013$) and shorter ET (224.18 ± 49.96 ms vs. 280.90 ± 46.12 ms, $p = 0.001$), while IVRT, IVCT, and MPI were significantly higher (95.25 ± 19.22 ms vs. 68.48 ± 12.77 ms, $p = 0.001$; 81.62 ± 23.59 ms vs. 60.90 ± 17.38 ms, $p = 0.001$; and 0.82 ± 0.222 vs. 0.47 ± 0.10, $p = 0.001$, respectively). There were no significant differences between patients groups regarding left ventricular ejection fraction, systolic pulmonary artery pressure, right ventricular dimensions, and TAPSE (Table 2).

Indices of RV function (TAPSE, Sm, and MPI) were entered simultaneously into a multivariate regression model. It showed that MPI was the only parameter that retained its significant association with proximal RCA lesions pointing to it being an independent predictor ($p = 0001$) (Table 3).

The receiver operator characteristic curve for MPI showed areas under the curve of 97% and a confidence interval of 93%. A cut-off value of 0.58 for MPI had a sensitivity of 95% and specificity of 97% for the diagnosis proximal RCA (Fig. 1, Table 4).

Discussion

Identifying the culprit artery is important for risk stratification and optimizing treatment strategies for patients with acute IWMI. The mortality for IWMI with RVI due to proximal RCA lesions is high: it is 16% compared with 3.5% for isolated inferior MIs [19].

ECG directs the emergency treatment pathways and helps with predicting the culprit artery. However, the sensitivity for conventional ECG

Table 2. Echocardiographic parameters of patient groups.

	A (43 patients)	B (33patients)	*p* value
LVEF (%)	47.44 ± 6.11	46.72 ± 7.50	0.64
SPAP mmHg (mean ± SD)	27.48 ± 5.90	27.18 ± 7.72	0.84
RVD mm (mean ± SD)	34.97 ± 5	33.30 ± 5	0.188
TAPSE mm (mean ± SD)	20.28 ± 7.78	20.51 ± 5.51	0.89
Sm cm/s (mean ± SD)	10.44 ± 2.61	12.11 ± 2.94	0.013
Em cm/s (mean ± SD)	9.05 ± 3.32	9.17 ± 2.38	0.86
Am cm/s (mean ± SD)	11.51 ± 3.67	14.43 ± 3.15	0.5
IVRT ms (mean ± SD)	95.25 ± 19.22	68.48 ± 12.77	0.001
IVCT ms (mean ± SD)	81.62 ± 23.59	60.90 ± 17.38	0.001
ET ms (mean ± SD)	224.18 ± 49.96	280.90 ± 46.12	0.001
MPI	0.82 ± 0.222	0.47 ± 0.10	0.001

ET = ejection time; IVCT = isovolumic contraction time; IVRT = isovolumic relaxation time; LVEF = left ventricular ejection fraction; MPI = myocardial performance index; RVD = right ventricular dimension; SPAP = systolic pulmonary artery pressure; TAPSE = tricuspid annular plan systolic excursion.

Table 3. Multiple regression analysis.

Variables	B	SD	Wald	Sig	Exp(B)	95% C.I for EXP(B)	
						Lower	Upper
MPI	23.162	6.049	14.660	0.000	1.1146E+10	8174.294	1.615E+15
TAPSE	−0.114	0.093	1.494	0.222	0.892	0.743	1.071
Sm	0.119	0.195	0.374	0.541	1.126	0.769	1.649
Constant	−12.895	4.314	8.937	0.003	0.000		

C.I. = confidence interval; df. = difference; MPI. = myocardial performance index; S.E. = standard error; Sig. = significance; Sm. = peak systolic velocity; TAPSE. = tricuspid annular plan systolic excursion.

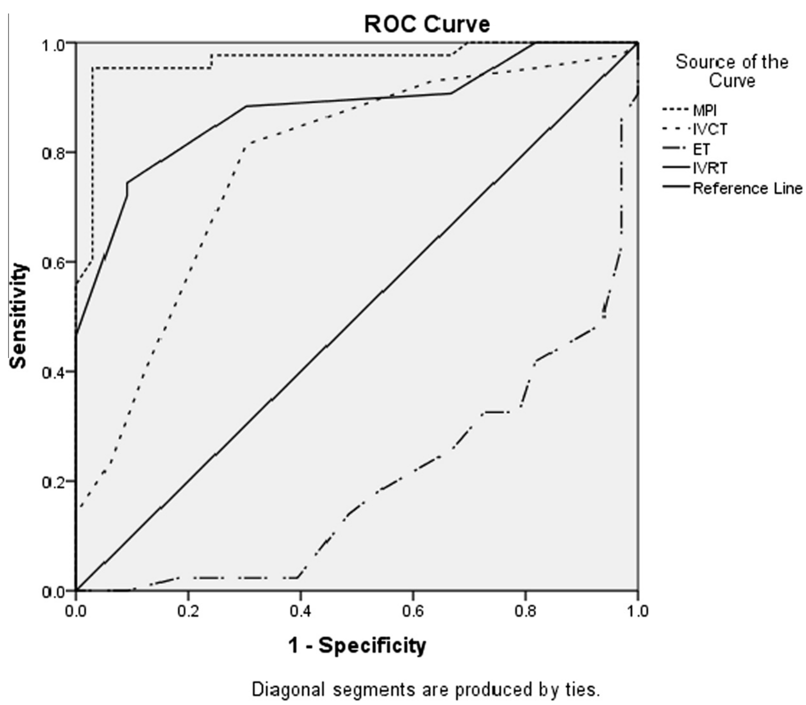

Figure 1. Receiver operator characteristic curve for myocardial performance index. MPI = myocardial performance index; ROC = receiver operator characteristic.

Table 4. ROC of MPI showed area under curve 97% and significance 0.001.

Variable(s)	Area	Std. error	Sig.	95% Confidence interval	
				Lower bound	Lower bound
MPI	0.967	0.021	0.001	0.927	1.000

MPI = myocardial performance index; Sig. = significance; Std. = standard.

criteria is low for identifying the culprit artery in inferior STEMI [20–24].

Echocardiography has become the mainstay in the evaluation of the RV in daily clinical practice. However, the complex RV geometry poses significant difficulties in the assessment of RV function [25,26]. Limited studies validating the utility of various Echocardiographic parameters of RV function in patients with proximal RCA stenosis. In this study, we aimed to assess the validity of different ECG parameters assessing RV function for the prediction of proximal RCA lesion.

In our study, there was no significant difference in ischemic heart disease risk factors between patients with proximal and distal RCA stenosis, and the incidence of arrhythmia was 25.6% in patients with proximal RCA; this is in accordance with a previous study [27]. Troponin I was significantly higher in patients with proximal RCA lesions compared with patients with distal RCA lesions. This is because of greater myocardium at jeopardy in proximally located culprit lesions.

At the time of presentation, there were no significant differences in hemodynamics, left ventricular, ejection fraction, and RV dimension between patients with proximal and distal RCA lesions. This can be explained by the fact that RVMI can lead to various degrees of myocardial ischemia and does not always lead to hemodynamic impairment [28,29]. Furthermore, there was no significant difference in RVSP derived from TR between patients with proximal versus distal RCA stenosis. The RVSP derived from TR is mainly load-dependent and does not reflect the contractile status of the RV muscle [30].

RV function parameters

In our study, the proximal RCA group had a significantly higher incidence of RVMI than patients with distal RCA This is in accordance with previous studies [31], and this can explain the reduction of RV function parameters in this subgroup of patients.

In our study, there was no significant difference between TAPSE measurements in patients with proximal and distal RCA stenosis. This can be explained by the fact that TAPSEs carry the inherent limitation of estimating global function of a complex structure from a single-segment analysis [18]. Also, TAPSE cut off has a high specificity but low sensitivity to differentiate abnormal from normal patients [32].

In our study, Sm was significantly lower in patients with proximal RCA in comparison to those with distal RCA lesions and thus was able to differentiate proximal from distal RCA stenosis. This is in accordance with a previous study by Ozdemir et al. [33]who stated that Sm significantly correlates with proximal RCA in patients with IWMI; this is also in accordance with Dokainish et al. [34], who concluded that tricuspid Sm can predict RVMI, and Wang et al. [35], who compared tricuspid Sm with RV ejection fraction evaluated with cardiac magnetic resonance and found that tricuspid Sm presented the best correlation with RVEF with cardiac magnetic resonance. Also, Alam et al. [36] concluded that Sm and TAPSE can be used to assess RV function in association with IWMI.

In normal RV with preserved contractility and under normal loading conditions, the end of systolic movement is immediately followed by early filling, and the RV IVRT is very short or may even be absent. Therefore, a measurable IVRT is an indicator of elevated end-systolic RV pressure [37]. In our study, the RV IVRT was significantly prolonged and ET was significantly shorter in patients with proximal RCA compared with patients with distal RCA. This is because there was a significantly higher number of RVMI in patients with proximal RCA.

In our study, MPI was significantly higher in patients with proximal RCA. This was due to the prolongation of IVCT and shortening of ET.

The MPI index is derived from physiological rather than structural features and combining information from both systolic and diastolic phases of the cardiac cycle [38]; therefore, it can give a global estimate of RV function with good sensitivity and specificity for predicting a proximal RCA lesion. This is in accordance with Moller et al. [39] who concluded that in the hyperacute phase of MI, the MPI of both the left ventricle and RV is significantly higher compared with control patients [39].

Multiple regression analysis showed that the most powerful predictor for proximal RCA was

MPI. A cut-off value of 0.58 for MPI had a sensitivity of 95% and specificity of 97% for the diagnosis proximal RCA. Conclusion MPI may help in the prediction of proximal versus distal RCA lesions. Identifying such a subgroup of patients early in their presentation using an MPI cut-off value may help in the early assessment and management of RVI.

Recommendation

Further study focusing on echocardiographic measurements after reperfusion treatment to investigate speed of recovery.

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