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The Correlation between the Right Ventricular Strain and the Severity of Right Coronary Artery Lesions in Patients with Stable Coronary Artery Disease

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ABSTRACT

Background A recent study demonstrated that in patients with stable coronary artery disease who were indicated for coronary angiography and it resulted in single proximal RCA significant lesion and 2D echocardiography was normal, speckle tracking on RV free wall detected significant impact on its segments and its global strain.

Aim of the Work: To correlate between the RV strain and the degree of RCA stenosis in patients with stable Angina.

Methods: a prospective observational study done included large number of persons complaining of typical anginal pain indicated for coronary angiography. Conventional 2D TTE was done and we excluded patients with RV dysfunction or RV dilatation. Speckle tracking on RV was done before doing coronary angiography. Patients with single ostial, para ostial or proximal dominant RCA lesions were chose to correlate their degree of stenosis with right ventricular free wall and RV global strain speckle tracking. Also, control group with normal speckle tracking and normal coronary angiography was taken in the study. Data was collected & coded using Microsoft Office Excel

Worksheet while statistical analysis was performed using statistical package for social sciences (SPSS) version
Results: The study showed that regarding the Echocardiography parameters, there were statistically significant difference between the 2 groups regarding the B RVFW, MRVFW, APRVFW and GLsRV.

Significant relation was detected between degree of the proximal RCA stenotic lesion and speckle tracking parameters of RVFW and GLsRV.

Conclusion: RVFWLS and GLsRV has highly significant correlation with the degree of the proximal stenotic lesion.

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Introduction

Echocardiography is the leading cardiac imaging technique in patients with suspected cardiac disease. However, conventional echocardiography at rest provides little information regarding the presence and extent of coronary artery disease in patients suspected of suffering from stable angina pectoris [1]. Longitudinally orientated myocardial fibers are located subendocardially, the area most susceptible to ischemia, that is why measurements of longitudinal motion and deformation may be the most sensitive markers of CAD using tissue Doppler imaging or two-dimensional strain echocardiography (2DSE) [2]. The analysis of myocardial deformation has emerged as a quantitative means of reliably estimating myocardial contractility.

Stress imaging techniques have several advantages over conventional exercise ECG testing including superior diagnostic performance for the detection of obstructive coronary disease, the ability to quantify and localize areas of ischemia, and the ability to provide diagnostic information in the presence of resting ECG abnormalities or inability of the patient to exercise [3]. So, the aim of this study was to determine the correlation between 2DSE of RV at rest and degree of stenotic lesion in the (pre RV branch) dominant RCA which was known by coronary angiography in stable angina pectoris patients.

Patients and Methods

Study Population

The present study included 60 patients suspected to be stable angina pectoris patients. All patients were presented for evaluation of chest pain at our outpatient clinics, Echocardiography and

Cath lab of Bab EL-She'riya University Hospital– Al-Azhar University–Cairo–Egypt, were considered to participate in this study. Conventional 2D TTE was done and we excluded patients with RV dysfunction or RV dilatation. Speckle tracking on RV was done before doing coronary angiography. Patients with single ostial, para ostial or proximal (dominant RCA) lesions were chosen to correlate their degree of RCA stenosis with RVFW speckle tracking

The patients were classified according to coronary angiography results into two groups: Group (A) (control group): 20 patients with normal coronary angiography considered as a control. Group (B) (patient group): 40 patients with CAD, their ages range from 35 to 67 years. Inclusion criteria: Stable angina pectoris was defined as chest pain or discomfort (angina) suspected to be due to myocardial ischemia. Symptoms of angina will be considered stable if they have been occurring over several weeks without deterioration and typically induced by activity or stress.

Inclusion Criteria: included subjects with dominant RCA and lesions in the proximal segments to be sure that the lesion is before the RV branch which supplies the right ventricle.

Exclusion criteria: Acute coronary syndrome patients, prior myocardial infarction, prior coronary interventions, left ventricular ejection fraction ≤ 50%, significant regional wall motion abnormalities, congestive heart failure, atrial fibrillation, valvular heart disease, cardiomyopathies, congenital heart disease, technically poor acoustic window for transthoracic echocardiography, impaired RV function and patients with dilated RV or pulmonary hypertension. Informed consent was taken from all patients.

Complete history and full physical examination were done to all patients. The history highlighted the duration of chest pain, diabetes mellitus, smoking, hypertension, dyslipidemia and family history.

Full clinical examination was carried out on every patient. Resting standard 12-leads electrocardiogram searching for rate, rhythm, bundle branch block and chamber enlargement and ischemic changes.

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Echocardiography: A Philips IE 33 X Matrix phased array system equipped with TDI & STE technology, using a multi frequency (1-5 MHz) S5-1 matrix array probe was used. Images were obtained with patients in the left lateral decubitus position Data acquisition was performed at a depth of 16 cm in the parasternal and apical views using a commercially available machine (Philips, IE 33) 3.5-MHz transducer. During breath-hold, M-mode and 2D images were obtained and 3 consecutive beats beats were saved in cine loop format [4].

The LV end-systolic volume (LVESV) end-diastolic volume (LVEDV) were assessed and LV ejection fraction (LVEF) was calculated using the biplane Simpson method, from apical two and four chamber views. In addition, the LV was divided into 16 segments, and each segment was analyzed individually and scored based on its motion and systolic thickening (1, normokinesis; 2, hypokinesis; 3, akinesis; and 4, dyskinesis). Subsequently, wall motion score index (WMSI) was calculated as the sum of the segment scores divided by the number of segments scored. Left atrial (LA) size was quantified by calculating the volume according to the ellipsoid model [4].

RV Function Analysis

RV fractional area change (RVFAC) was analyzed by tracing the RV` end-diastolic area (RVDA) and end-systolic area (RVSA) in the apical 4-chamber view using the formula (RVDA-RVSA)/ RVDA_100 [4].

Tricuspid annular plane systolic excursion was measured in the RV free wall. In the 4-chamber view, the M-mode cursor was placed through the tricuspid annulus in such a way that the annulus moved along the M-mode cursor and the total displacement of the RV base from end-diastole to end-systole was measured.

Speckle Tracking Echocardiography Study: All studies were done before coronary angiography. The apical 4 chambers view was taken for later analysis. Peak systolic longitudinal strain of the RV free wall was measured in the 4-chamber view using speckle-tracking analysis; this software analyzes motion by tracking frame-to-frame movement of natural acoustic markers in 2 dimensions.

All images were recorded with a frame rate of 40 fps for reliable analysis).
The RV endocardial border was manually traced at end-systole and the automatically created region of interest was adjusted to the thickness of the myocardium. Peak systolic longitudinal strain was determined in the 3 segments of the RV free wall (basal, mid, and apical), and RV strain was calculated as the mean value of all segments. Segments were discarded if tracking was of poor quality. Strain analysis was feasible in 85% of segments [5].

Coronary Angiography: Coronary angiograms were obtained for each coronary vessel in at least two projections. Lesion locations were assessed and percent diameter stenosis was measured for each coronary lesion according to the American Heart Association

classification. We assessed the degree of the RCA stenotic lesion, using a cutoff of percent diameter stenosis ≥ 70%, 50-70 % and less than 50 % stenosis. The analysis of the coronary angiograms was performed visually by an experienced operator who was blinded to the results of the echocardiographic examinations and by the QCA [6].

Statistical Analysis

The collected data were revised, organized, tabulated and statistically analyzed using statistical package for social sciences (SPSS) version 23.0 for windows. Data are presented as the Mean ± standard deviation (SD), frequency, and percentage. Categorical variables were compared using the chi-square ($\chi 2$) and Fisher's exact tests (if required). Continuous variables were compared by the Student t test (two-tailed) and one – way ANOVA test for parametric data with Bonferroni post hoc test to detect differences between subgroups. The level of significance was accepted if the P value < 0.05.

Results

In this study, there was no statistically significant difference between the control and patient groups according to risk factors (Table1).

Table 1: shows no statistically significant difference between the control and patient groups according to risk factors

Risk Factors	Patient	Control	t#/x2	p-value
Age (years)				
Mean±SD	49.83±8.94	50.25±9.00	0.030#	0.863
Range	35-66	37-67		
Sex				
Female	19 (47.5%)	9 (45.0%)	0.033	0.855
Male	21 (52.5%)	11 (55.0%)		
DM	15 (37.5%)	7 (35.0%)	0.036	0.850
HTN	20 (50.0%)	8 (40.0%)	0.536	0.464
Smoking	19 (47.5%)	12 (60.0%)	0.834	0.361
Dyslipedemia	21 (52.5%)	9 (45.0%)	0.300	0.584

The study showed highly statistically significant difference between control and patient groups according to CCS angina (Table2).

Table 2: shows highly statistically significant difference between groups according to CCS angina

CCS ANGINA	Patient	Control	x2	p-value
I	0 (0.0%)	13 (65.0%)	35.182	<0.001
II	26 (65.0%)	7 (35.0%)		
III	14 (35.0%)	0 (0.0%)		

The study showed no statistically significant difference between groups according to conventional 2D echocardiography (Table 3)

Table 3: shows no statistically significant difference between groups according to conventional 2D echocardiography

2D Echocardiography	Patient	Control	t-test	p-value
LVEDD Mean±SD 36.5-60	 46.87±5.42 36.5-60	 47.09±3.23 41.2-52.2	0.028	0.868
LVESD Mean±SD Range	 31.30±5.48 20.7-40.8	 30.37±2.81 26-35	0.507	0.479
EF SIM Mean±SD Range	 57.18±2.54 52-61	 57.77±5.21 49.3-69.3	0.357	0.553
LAD Mean±SD Range	 35.46±4.90 26-44	 37.25±8.56 26-57	1.068	0.306
FAC Mean±SD Range	 45.56±7.39 32.3-61.5	 45.59±6.53 33.3-57.1	0.000	0.989
TAPSE Mean±SD Range	 22.68±2.87 16-28	 21.15±3.03 16-27	3.631	3.631

The study showed no statistically significant relatio between the degree of the lesion and the risk factors Table (4).

Table 4: Shows no statistically significant relation between the degree of the lesion and the risk factors

Risk Factors	Coronary Angiography (CA RCA%)			F#/x2	p-value
	<50%	50-70%	>70%		
Age (years)	48.13±9.96	51.07±9.13	50.80±7.24	0.471#	0.628
Sex					
Female	7 (43.8%)	5 (35.7%)	7 (70.0%)	2.900	0.235
Male	9 (56.3%)	9 (64.3%)	3 (30.0%)		
DM	3 (18.8%)	7 (50.0%)	5 (50.0%)	4.001	0.135
HTN	9 (56.3%)	7 (50.0%)	4 (40.0%)	0.650	0.723
Smoking	8 (50.0%)	8 (57.1%)	3 (30.0%)	1.790	0.409

The study showed statistically significant relation between the degree of the RCA lesion and the grade of CCS angina Table (5).

Table 5: Shows statistically significant relation between the degree of the RCA lesion and the grade of CCS angina

	Coronary Angiography (CA RCA%)			x2	p-value
	<50%	50-70%	>70%		
	15 (93.8%)	10 (71.4%)	1 (10.0%)	19.364	<0.001
	1 (6.3%)	4 (28.6%)	9 (90.0%)		

The study showed statistically significant relation between the degree of the RCA lesion and the FAC and no relation with other echocardiography parameters Table (6).

Table 6: Shows statistically significant relation between the degree of the RCA lesion and the FAC and no relation with other echocardiography parameters

2D Echocardiography	Coronary Angiography (CA RCA%)			ANOVA	p-value
	<50%	50-70%	>70%		
LVEDD	47.83±3.01	45.37±5.46	47.41±8.00	0.827	0.445
LVESD	32.02±3.97	29.81±5.65	32.21±7.24	0.782	0.465
EF SIM	56.75±2.49	57.71±2.13	57.10±3.21	0.530	0.593
LAD	35.84±4.90	34.66±4.50	35.97±5.75	0.279	0.758
FAC	49.30±4.78	43.11±4.15	42.99±11.50	3.935	0.028
TAPSE	23.63±1.86	22.07±2.23	22.00±4.47	1.503	0.236
RVSP	35.31±7.53	35.93±5.25	32.70±7.96	0.686	0.510

The study showed statistically significant difference between control and patient groups according to B RVFW, MRVFW, APRVFW and GLsRV Table (7).

Table 7: shows statistically significant difference between control and patient groups according to B RVFW, MRVFW, APRVFW and GLsRV

Speckle tracking	Patient	Control	t-test	p-value
B RVFW Mean±SD Range	 -18.50±5.24 -27_-6	 -22.20±2.07 -26_-19	9.180	0.004
M RVFW Mean±SD Range	 -18.75±4.99 -28_A-8	 -21.40±1.82 -25_A-18	5.251	0.026
AP RVFW Mean±SD Range	 -18.13±5.13 -28_A-7	 -20.55±2.01 -25_A-17	3.874	0.047
GLs RV Mean±SD Range	 -18.73±4.88 -27_A-7	 -21.10±1.74 -25_A-18	4.425	0.040

The study showed statistically significant relation between the degree of the RCA lesion and parameters of speckle tracking. Table (8), Figures (1),(2),(3),(4).

Table 8: shows statistically significant relation between the degree of the RCA lesion and parameters of speckle tracking

Speckle tracking	Coronary Angiography (CA RCA%)			ANOVA	p-value
	<50%	50-70%	>70%		
B RVFW	-23.13±2.96	-18.29±1.68	-11.40±2.80	65.56	<0.001
M RVFW	-22.69±2.70	-19.29±2.13	-11.70±2.45	62.31	<0.001
AP RVFW	-22.94±2.46	-18.14±1.70	-11.20±2.35	88.06	<0.001
GLs RV	-22.94±2.08	-18.93±1.27	-11.70±2.67	95.98	<0.001

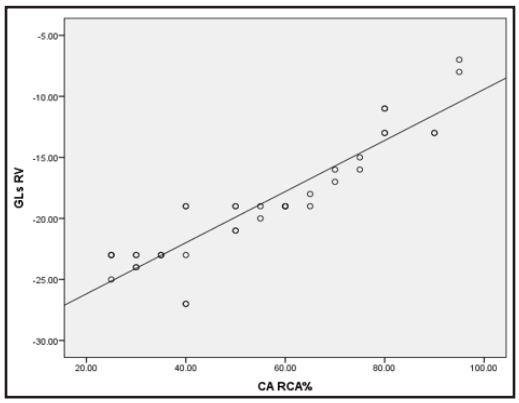

Figure 1: Correlation between the degree of RCA stenotic lesion with GLsRV

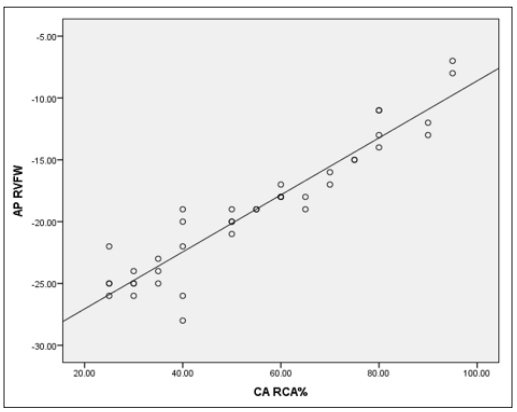

Figure 2: Correlation between the degree of RCA stenotic lesion with APRV FW

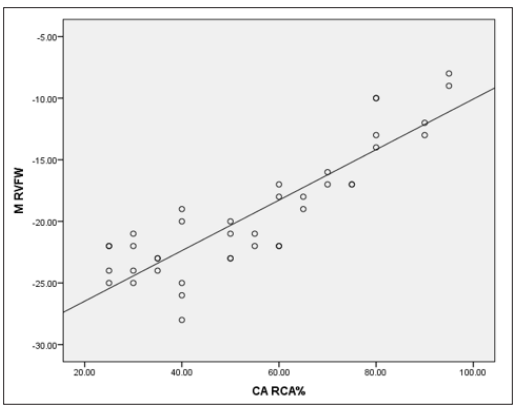

Figure 3: Correlation between the degree of RCA stenotic lesion with MRV FW

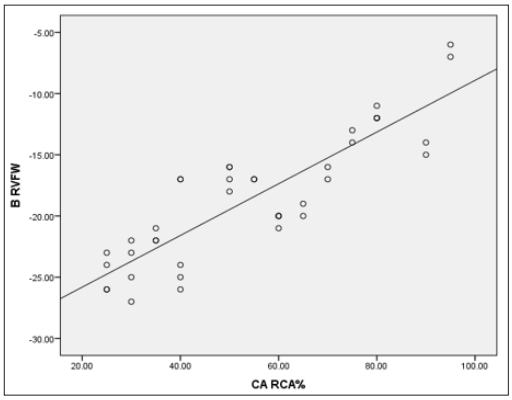

Figure 4: Correlation between the degree of RCA stenotic lesion with BRV FW.

Discussion

In the present study, RVLS-FW was significantly impaired in patients with pRCA involvement. Subtle RV dysfunction could be detected by STE but not by traditional methods for assessing RV function.

Diagnosis of RCA Lesions or RV Involvement by RV Free Wall Strain

RV dysfunction complicates and increases long-term mortality but is difficult to detect early [7]. In acute inferior myocardial infarction, ST-segment elevation in lead V4R is a widely used diagnostic method, but it is difficult to apply in patients with conduction abnormalities [8].

In addition, in patients with stable angina, chronic myocardial ischemia or dysfunction cannot usually be detected on electrocardiography. Other diagnostic modalities, including traditional echocardiography, Doppler tissue imaging, Swan-Ganz catheterization, and cardiovascular magnetic resonance imaging, are also limited in providing higher recognition of RV dysfunction [7]. STE has also been shown to be feasible in the diagnosis of CAD in patients without regional wall motion abnormalities or under hemodialysis [6,9]. However, all of these studies focused on LV strain. The present study demonstrated that STE can also be applied to identify RV involvement in patients with stable CAD and identify the correlation between the degree of the pRCA lesion and the value of the RVFW LS.

With respect to detecting RV infarction by deformation images, two studies have been published on patients with inferior myocardial infarctions. One showed that systolic tissue velocity, strain, and strain rates of the basal and mid segments of the right ventricle were significantly lower in patients with RV infarctions than in patients without infarctions [10]. Another study used myocardial performance index of the lateral tricuspid annulus as a

discriminatory parameter to identify RV infarction [11]. However, both of these studies focused on acute myocardial infarction and did not include patients without RV infarctions. In contrast, our study provided the access not only to identify RV involvement without overt RV myocardial infarction by a noninvasive modality, but also to predict the site and the degree of the RCA lesion. To the best of our knowledge, this is the second study to show the attenuation of RV strain in chronic RCA disease by using STE. In this study, RVLS-FW was better for the detection of pRCA lesions than other traditional echocardiographic parameters of RV assessment. Except for some uncommon left coronary artery–induced RV ischemia, this result is consistent with our hypothesis that in patients with stable angina, subtle ischemia-induced systolic dysfunction of the RV can be detected by longitudinal strain.

Previous literature has demonstrated that not only CAD but hypertension and diabetes can also affect LV longitudinal strain [12]. In this study, we also found that diabetes and hypertension did not affect RV strain and this agrees with Chang. This finding is important because diabetes and hypertension often coexist with CAD, and RV strain can be used for diagnosis in these situations.

Chang showed that there was Impaired RVLS-FW with RCA involvement was more pronounced in certain subgroups, including those with older age, hypertension and diabetes .This disagrees with our results as we found there was no affection in the control group and the patient group with non significant lesion. Chang worked mainly on patients with significant lesion which affected the RVLS, those patients had many risk factors and this might be the misleading cause.

With regard to the general echocardiographic parameters, LV ejection fraction, diastolic pressure, RV systolic pressure, and chamber dimensions were not significantly different between the control and the patient groups and this agrees with Chang results.

For RV function, there were no differences in RV FAC and TAPSE relating to RCA involvement. However, both right and left deformation markers, GLS and RVLS-FW were significantly impaired in the RCA affected group, especially in patients with more than 50 % lesion and this agrees with Chang et al results.

We divided the affected RCA patients into 3 subgroups; less than 50 % stenosis, 50-70 % stenosis and more than 70 % stenosis and found that the values of RVFW LS (basal, mid and apical) are correlated with the degree of stenosis as shown in Table 8.

Territorial Analysis of Regional RV Strain

In our study, RVLS-FW decreased significantly in magnitude among patients with RV ischemia, but using individual segmental strains was of no additional diagnostic value, which is comparable with other studies. The most likely reasons for the lower diagnostic rate for disease territory are the limited window to observe the right ventricle, interplay between the two ventricles, and collateral flow from different coronary arteries.

Although TAPSE is often used to evaluate RV function using conventional two-dimensional echocardiography, this measure does not take into account segmental RV function, which is crucial to analyze in detecting CAD. Another limitation is that a cutoff value of <17 mm has high specificity but low sensitivity to differentiate abnormal from normal subjects, so occult RV dysfunction may be ignored.

Limitations

The major limitation of this study was the restrictive window to observe the right ventricle. The limited angle makes the definition of specific segments in the apical view difficult, which may curtail the predictive rate of regional strain or strain rate. Deformation of the right ventricle may also be affected by other coexisting diseases, such as pulmonary hypertension, although we excluded possible factors affecting RV deformation during subject selection. Finally, there was a lack of a normative range of RV function evaluated by STE.

We could recruit a test group and measure false-positive and false-negative values. However, we were not able to recruit another group of patients with CAD large enough to validate the RV GLS cutoff value. FFR and IVUS were not available to identify the significance of the lesion. Also, physiological assessment was not available to correlate with the impact of the lesion.

Conclusions

RVLS-FW and GLs were independently impaired in patients with CAD with RCA stenosis, especially in proximal lesions with involvement of an acute marginal branch. RV strain can be used for the detection of occult RV dysfunction and the prediction of pRCA lesions in patients with stable CAD and predict the the degree of the lesion [13].

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