



Right Atrial Geometric Changes in Patients with Proximal versus Distal Significant Right Coronary Artery Stenosis: a Tissue Doppler imaging study

Authors

Lamiaa Khedr MD, Ehab Alguindy MD, Mohamed Abdelaal* MD,
Hatem Elsokkary MD

Cardiology Department, Tanta University Hospital, Egypt

*Corresponding Author

Mohamed Abdelaal

Email: abd_alaal@yahoo.com, Contact number: 00201003746301

Abstract

Background: Right atrial (RA) function is rarely investigated. Atrial contribution to the cardiac function is very important, atrial function was affected in many disease states including ischemic heart disease

Subjects and Methods: This study investigated the RA function in patients with significant right coronary artery (RCA) stenosis. Patients were divided into 3 groups: group one included 15 patients with significant proximal RCA stenosis, group two included 15 patients with significant distal RCA stenosis and group three included 15 normal subjects as a control group. We measured the RA maximum and minimum volume and RA distensibility. We measured RA function using atrial longitudinal systolic strain and strain rate using 2D color-coded Tissue Doppler imaging (TDI) applied to right atrium using standard apical 4ch view.

Results: We found no significant difference between the three groups regarding the RA maximal, minimal volume and distensibility. We found the RA longitudinal systolic strain and strain rate to be significantly reduced in patients with group one than patients in group two and three as the RA free wall systolic strain in group one was found to be 21.43 ± 9.55 , 59.65 ± 25.55 and 62.45 ± 28.73 in group one, two and three respectively. RA septal longitudinal systolic strain was found to be 12.96 ± 4.13 , 26.66 ± 11.5 and 25.97 ± 12.45 in group one, two and three respectively with p value 0.001. RA lateral wall longitudinal systolic strain rate was found to be 1.6 ± 0.57 , $2.8-12.9$ and 5.8 ± 2.37 in group one, two and three respectively with p value 0.001. RA septal wall longitudinal systolic strain rate was found to be 1.52 ± 0.52 , 2.54 ± 1.03 and 2.44 ± 1.01 in group one, two and three respectively with p value 0.004.

Conclusion: RA systolic function was found to be reduced in patients with proximal significant RCA stenosis. This finding may have therapeutic implication for the management of such patients.

Keywords: (right atrium, systolic function, tissue Doppler imaging, ischemic heart disease, right coronary artery).

Introduction

Coronary artery disease (CAD) is a major health problem as patients are at high risk to develop heart failure ^[1]. Impairment of the diastolic function is often present in patients with

significant CAD, even before the development of regional or global LV systolic dysfunction, therefore this might serve as an early and sensitive indicator of ischemia ^{[1],[2]}. It is obvious that the atrial function is an integral part of the cardiac

function. Atrial function consists of reservoir, conduit, active contractile function and booster pump for venous blood returning to the heart [3]. Strain and strain rate have also been used to detect myocardial dysfunction caused by various disease states including ischemic heart disease [4]. Defined as a measure of fiber deformation, strain is expressed as percent change to the segment length as compared to its length before deformation while strain rate is defined as strain per unit time [5]. The atrial reservoir function is represented by atrial systolic strain and strain rate while the conduit and contractile functions are represented by early and late diastolic strain rate respectively [6]. Impairment of the atrial systolic function occurs early in the course of ischemic heart disease [7]. Changes in the atrial function and size have been used as a marker for cardiovascular adverse outcome [8].

Aim of the work

The aim of this study is to evaluate the function of the right atrium in patients with significant right coronary artery stenosis (proximal versus distal segment) with conventional echocardiography, strain and strain rate imaging.

Subjects and Methods

This study included 30 patients with significant right coronary artery (RCA) disease who did coronary angiography in the cardiology department, Tanta university hospital during the period from January 2016 to December 2016. Patients were divided according to the results of the coronary angiography into two groups: group (one) included 15 patients with significant proximal RCA lesion and group (two) which included 15 patients with distal significant RCA lesion. A third group included 15 age and sex matched healthy adults without history of ischemic heart disease as a control group.

Inclusion Criteria: Patients with coronary artery disease who did coronary angiography and showed significant RCA lesion which is defined

as $\geq 50\%$ luminal stenosis were included in the study.

Exclusion Criteria: Elderly patients (age ≥ 65 years), obese patients with BMI ≥ 30 , patients with valvular heart disease, patients with arrhythmia especially atrial fibrillation (AF), patients with advanced renal or hepatic disease, patients with pulmonary hypertension, patients with chronic obstructive pulmonary disease (COPD) and patients with significant non RCA lesion were excluded.

All individuals were subjected to the following: detailed history taking, clinical examination and electrocardiogram (ECG). Blood was extracted for: lipid profile, liver and kidney function tests, fasting and postprandial blood glucose level.

Coronary angiography was done for group one and two. Patients with significant RCA lesion (as defined earlier) were included in the study.

Transthoracic echocardiography was done using (Vivid 7 dimension; General Electric Medical Systems, Horten, Norway) equipped with a 2.5-MHz variable-frequency transducer. Standard echocardiographic views were used.

For data acquisition 3 complete cardiac cycles were obtained and stored in cine loop format with the patient at rest and lying in the left lateral position. LV systolic function was obtained using simpson method.

Using biplane area-length method, the right atrial (RA) volume was obtained in the apical 4 chamber (4ch) view as follows:

RA volume = $(0.85 \times \text{area } 4\text{ch} \times \text{area } 4\text{ch}) / (\text{longest RA length})$ [9].

Using apical 4 chamber view the RA length and area were obtained at the end of ventricular systole. RA area was obtained by tracing endocardial border of the atrium excluding subannular plane, SVC & IVC and RA appendage.

RA long axis dimension was measured as a line perpendicular to the tricuspid annular plane extending to the back wall of RA. Atrial volumes obtained were indexed to the subject's body surface area [10].

RA dispensability was calculated as follows: $(V_{\max} - V_{\min}) \times 100 / (V_{\min})^{[11]}$.

where V_{\max} is the maximum volume of the atrium measured at the end of the systole (T wave on ECG) and V_{\min} is the minimum volume of the atrium measured at the end of diastole (R wave on ECG).

Right atrium was assessed by strain and strain rate as follows: Atrial longitudinal systolic Strain S and SR were measured using 2D color-coded Tissue Doppler imaging (TDI) applied to RA using standard apical 4ch view, by placing the sample volume (preferably 2mm because of thin atrial wall) at the mid segment of RA free and septal walls^[12]. Strain S /SR velocity profiles obtained were stored in digital format and analyzed offline with dedicated software at the interval between mitral valve closure (MVC) and mitral valve opening (MVO) to assess atrial reservoir function during ventricular systole. Peak positive systolic strain and strain rate values were calculated from the extracted curves over 3

recorded cardiac cycles to obtain mean strain and strain rate values of the studied atrial segment^[13].

Statistical Analysis

It was conducted, using the mean, standard deviation and chi-square test by SPSS V.20. Student t test was used to test the significance between two means. ANOVA test was used for comparison among different times in the same group in quantitative data. Chi-square test was used for comparison between two groups as regards qualitative data.

Results

The study included 3 groups:

Group one comprised 15 patients with proximal RCA significant stenosis, group two comprised 15 patients with distal RCA significant stenosis and group three comprised 15 normal subjects as control group. The demographic data of the three groups are represented in table (1).

Table (1) patients characteristics

		Group one	Group two	Group 3	F test	P value	P1	P2	P3
Age in years	Range	35-59	40-60	39-60	1.73	0.356	0.603	0.142	0.346
	mean±SD	45±9.6	50±8.1	45±8.6					
BMI	Range	23-28	22-28.5	23-28	0.613	0.531	0.946	0.319	0.669
	mean±SD	25±3.1	25.3±2.3	24.6±1.85					
Sex	Male/N%	9(60%)	8(53%)	8(53%)	X ² =0.483	0.762			
	Female/N%	6(40%)	7(47%)	7(47%)					
Smoking	Yes/N(%)	8(53%)	6(40%)	3(20%)	X ² =5.761	0.055			
	No/N(%)	7(47%)	9(60%)	12(80%)					

BMI= body mass index. P1 between group one and group two, p2 between group one and group three, p3 between group two and group three. P value is significant if <0.05.

Total cholesterol was found to be higher in group one and two compared to group three. P value (0.001) and 0.002 respectively. There was no significant difference between the three groups regarding left ventricular ejection fraction (EF), as EF was (63±2.8) in group one and (64±2.7) in group two and (67±3.5) in group three.

Right atrial minimal volume (RA Vmin) was found to be 5-16 ml/m² with mean ±SD=10.3±2.56 in group one. In group two the RA Vmin was

found to be 6-17 ml/m² with mean ±SD=10.15±2.33. In group three the RA Vmin was found to be 5.5-16 ml/m² with mean ±SD=9.9±2.78.

Right atrial maximal volume (RA Vmax) was found to be 16-30 ml/m² with mean ±SD=21±6.56 in group one. In group two the RA Vmax was found to be 12-31 ml/m² with mean ±SD= 21±5.8. In group 3 the RA Vmax was found to be 11-32 ml/m² with mean ±SD=19.54±6.43.

Right atrial (RA) distensibility was found to be 15.4-198 % with mean \pm SD=103.2 \pm 57.8 in group one. In group two RA distensibility was found to be 30-167 % with mean \pm SD=101.5 \pm 49.87. In group three the RA distensibility was found to be

51-187% with mean \pm SD=82.7 \pm 43.65. Table (two). There was no significant difference between the three groups of the study as regard RA Vmin, RA Vmax and RA distensibility as the p value was higher than 0.05 all the time.

Table (2): Echocardiographic assessment of right atrial volumes and distensibility:

		Group one	Group two	Group three	F. test	p. value	p1	p2	p3
RA Vmin	Range	5-16	6-17	5.5-16	0.399	0.656	0.411	0.425	0.954
	Mean \pm SD	10.3 \pm 2.56	10.15 \pm 2.33	9.9 \pm 2.78					
RA Vmax	Range	16-30	12-31	11 – 32	1.723	0.179	0.184	0.069	0.567
	Mean \pm SD	21 \pm 6.56	21 \pm 5.8	19.54 \pm 6.43					
RA Dist	Range	15.4-198%	30-167	51-187	1.350	0.237	0.407	0.111	0.344
	Mean \pm SD	103.2 \pm 57.8	101.5 \pm 49.87	82.7 \pm 43.65					

RA Vmin=Right atrial minimal volume, RA Vmax=Right atrial maximal volume, RA Dist= right atrial distensibility,P1 between group one and two, p2 between group one and three, p3 between two and three. Significant p value< 0.05

As regard RA free wall systolic strain (S%) it was found to be from 9-33% in group one with mean \pm SD= 21.43 \pm 9.55. In group two, the RA free wall systolic strain was found to be 32-128% with mean \pm SD= 59.65 \pm 25.55. In group three, the RA free wall systolic strain was found to be 37-133% with mean \pm SD= 62.45 \pm 28.73. There was

statistically significant difference between group one and two as p value was 0.001. There was also statistically significant difference between group one and three as p value was 0.001. There was no statistically significant difference between group two and three as p value was 0.355. Figure (1).

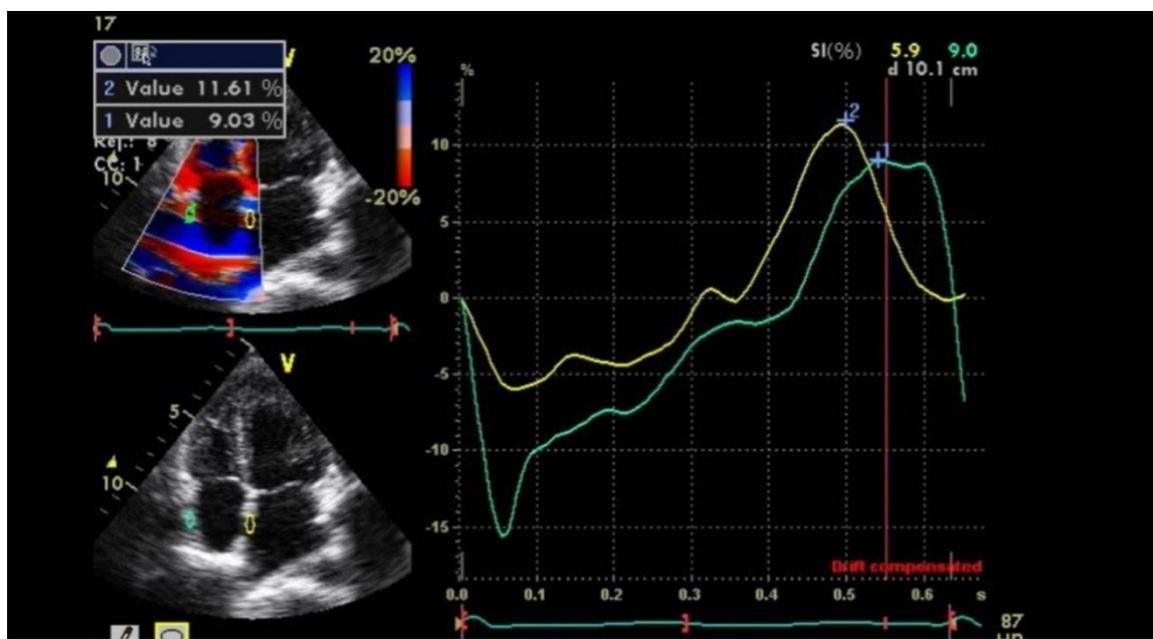


Figure (1): of patient in group one showing septal and lateral wall systolic strain of 11.61 and 9.03 % respectively.

Regarding the right atrial free wall systolic strain rate (SR) s⁻¹, in group one it was found to be 1.19-3.25 with mean \pm SD= 1.6 \pm 0.57. In group two

it was found to be 2.8-12.9 with mean \pm SD= 6.1 \pm 2.87. In group three it was found to be 2.57-13.3 with mean \pm SD= 5.8 \pm 2.37. There was

statistically significant difference between group one and two as p value was 0.001. There was also statistically significant difference between group

one and three as p value was 0.001. There was no statistically significant difference between group two and three as p value was 0.673. Table (3)

Table (3): Right atrial free wall systolic strain(S) % and strain rate (SR s⁻¹)

		Group one	Group two	Group three	F. test	p-value	p1	p2	p3
RA lateral S	Range	9-33	32-128	37-133	18.976	0.001	0.001	0.001	0.355
	Mean ± SD	21.43±9.55	59.65±25.5	62.45±28.73					
RA Lateral SR	Range	1.19-3.25	2.8-12.9	2.57-13.3	22.112	0.001	0.001	0.001	0.673
	Mean ± SD	1.6±0.57	6.1±2.87	5.8±2.37					

RA lateral S= right atrial free wall systolic strain (S%), RA lateral SR= right atrial strain rate (SR s⁻¹). P1 between group one and two, p2 between group one and three, p3 between group two and three. Significant p value <0.05.

Right atrial septal wall systolic strain (Septal S %) was found to be 5.5-19% with Mean±SD= 12.96±4.13 in group one. In group two it was found to be 10.9-47.99% with Mean ± SD= 26.66±11.5. In group three it was found to be 11.87-48.79% with Mean ± SD= 25.97±12.45. There was statistically significant difference between group one and two as p value was 0.023. There was also statistically significant difference between group one and three as p value was

0.001. There was no statistically significant difference between group two and three as p value was 0.075.

For right atrial septal wall systolic strain rate: it was found to be 1.2-2.45 % with mean± SD= 1.52±0.52 in group one. In group two it was found to be 1.32-4.32 % with mean ±SD= 2.54±1.03. In group three it was found to be 1.29-4.46 % with mean ±SD= 2.44±1.01. Figure (2)

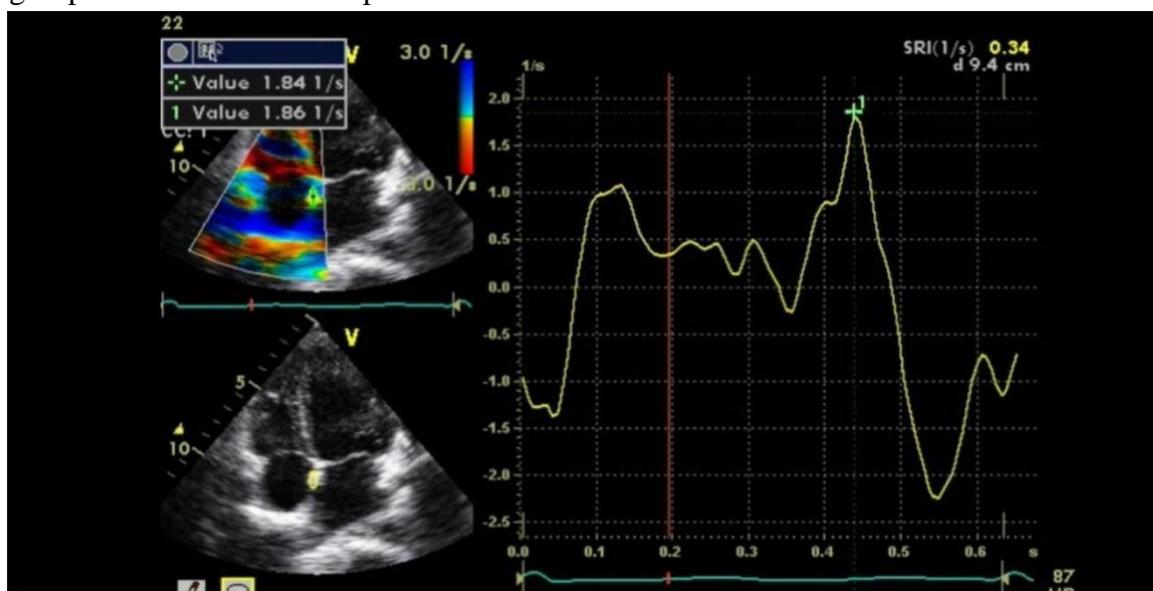


Figure (2): patient in group one with RA septal systolic strain rate of 1.86%

There was statistically significant difference between group one and two as p value was 0.016. There was also statistically significant difference between group one and three as p value was

0.021. There was no statistically significant difference between group two and three as p value was 0.077. Table (four)

Table 4: right atrial septal wall systolic strain and strain rate measures:

		Group one	Group two	Group three	F. test	p. value	p1	p2	p3
Septal S	Range	5.5-19	10.9-47.99	11.87-48.79	9.984	0.001	0.023	0.001	0.075
	Mean ± SD	12.96±4.13	26.66±11.5	25.97±12.45					
Septal SR	Range	1.2-2.45	1.32-4.32	1.29-4.46	4.556	0.004	0.016	0.21	0.77
	Mean ± SD	1.52±0.52	2.54±1.03	2.44±1.01					

S = strain, SR= strain rate.p1: between group one and two, p2: between group one and three, p3: between group two and three. Significant p value<0.05

Regarding the mean right atrial systolic strain, it was found to be 11.05-24.9% with Mean ± SD=16.96±4.46 in group one. In group two it was found to be 24.56-72.35% with Mean ± SD=47.83±13.46. In group three, it was found to be 25.96-70.98% with Mean ± SD=45.63±11.37. There was statistically significant difference between group one and two as p value was 0.001. There was also statistically significant difference between group one and three as p value was 0.001. There was no statistically significant difference between group two and three as p value was 0.091.

For the mean right atrial systolic strain rate, it was found to be 1.09-7.96 with Mean ± SD= 2.1±1.86. In group two it was found to be 1.99-8.7 with Mean ± SD= 4.19± 2.01. In group three it was found to be 1.87-8.64 with Mean ± SD= 4.01± 2.21.

There was statistically significant difference between group one and two as p value was 0.001. There was also statistically significant difference between group one and three as p value was 0.002. There was no statistically significant difference between group two and three as p value was 0.778. Figure (3), Table (5).

Table (5): Mean right atrial systolic strain(S)% and strain rate(SR) s⁻¹:

		Group one	Group two	Group three	F. test	p. value	p1	p2	p3
Mean RAS	Range	11.05-24.9	24.56-72.35	25.96-70.98	31.867	0.001	0.001	0.001	0.091
	Mean ± SD	16.96±4.46	47.83±13.46	45.63±11.37					
Mean RASR	Range	1.09-7.96	1.99-8.7	1.87-8.64	7.262	0.002	0.001	0.002	0.778
	Mean ± SD	2.1±1.86	4.19± 2.01	4.01± 2.21					

Mean RAS=Mean right atrial systolic strain. Mean RASR= mean right atrial systolic strain rate. P1 between group one and two, p2 between group one and three, p3 between group two and three.Significant p value <0.05.

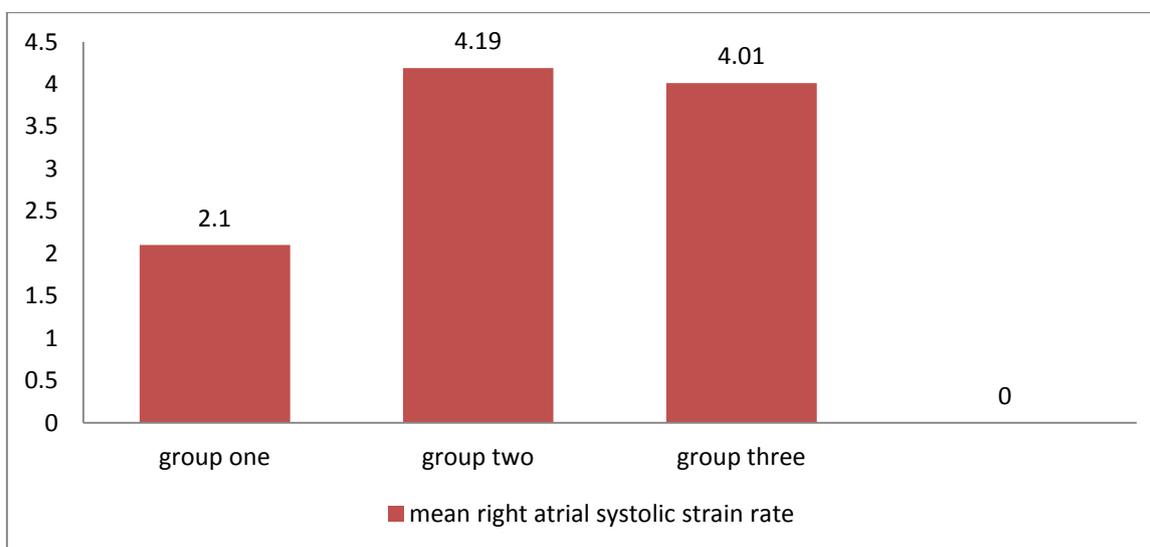


Figure (3): mean right atrial systolic strain rate.

Discussion

The atrium has a very important role in optimizing the cardiac function. During the ventricular systole it acts as reservoir, in early ventricular diastole it acts as a conduit and in late diastole it acts as a booster pump^[14]. In ischemic heart disease the atrial function may be primarily or secondarily affected and evaluation of the atrial function is an important step to assess the hemodynamic effect of the disease^[15]. Right atrium is relatively neglected chamber, and its function in various cardiac diseases especially ischemic heart disease are less explored. Right atrium plays an important role in endocrine and electromechanical regulation of the heart^[16]. To our knowledge, this is the first study to evaluate the RA function in IHD in relation to the level of RCA obstruction with tissue Doppler imaging. In this study, we investigated the geometric changes of the right atrium in patients with significant RCA stenosis. We studied 30 patients with significant RCA stenosis. They were divided into 2 groups according to the location of the RCA lesion: group one comprised 15 patients with proximal RCA stenosis, and group two comprised 15 patients with distal RCA stenosis. A third group comprised 15 normal subjects with no evidence of CAD as a control group. There was no statistically significant difference between the three groups regarding age, sex, BMI and left ventricular EF. Total cholesterol was higher in group one than in group two and three. We measured the RA minimal volume (RA V_{min}), RA maximal volume (RA V_{max}) and RA distensibility. We found the RA V_{min} to be 10.3±2.56 in group one, 10.15±2.33 in group two and 9.9 ±2.78 in group three. RA V_{max} was found to be 21±6.56 in group one, 21±5.8 in group two and 19.54±6.43 group three. RA distensibility was found to be 103.2±57.8 in group one, 101.5±49.87 in group two and 82.7±43.65 in group three. Regarding the RA minimal volume, maximal volume and distensibility there was no significant difference between the three groups as the p value was higher than 0.05 all the time.

These results were matched with the results of (Yu M.C et al)^[7]. They studied the atrial function in patients with IHD and compared it to normal subjects with tissue Doppler imaging. They found that there was no significant difference between the two groups regarding the RA volumes. The results of the present study were not matched with the results of Shinomiya H et al^[17] who studied the RA function with 2-D echocardiography. They found the RA volume to be greater in group one with proximal RCA lesion than in the other groups. This difference may be attributed to the fact that they measured RA area by single plane area method but we measured RA volumes by using biplane area-length method where we divided the area by the longest RA length.

The present study showed the RA strain and strain rate were lower in group one when compared to group two and three. The study found the RA free wall systolic strain to be 21.43±9.55 in group one, 59.65±25.55 in group two and 62.45±28.73 in group three. Regarding the RA free wall systolic strain rate (SR) s⁻¹ it was found to be 1.6±0.57 in group one, 6.1±2.87 in group two and 5.8±2.37 in group three. Right atrial septal wall systolic strain (Septal S %) was found to be 12.96±4.13 in group one, 26.66±11.5 in group two and 25.97±12.45 in group three. For right atrial septal wall systolic strain rate: it was found to be 1.52±0.52 in group one, 2.54±1.03 in group two and 2.44±1.01 in group three. Regarding the mean right atrial systolic strain, it was found to be 16.96±4.46 in group one, 47.83±13.46 in group two and 45.63±11.37 in group three. For the mean right atrial systolic strain rate, it was found to be 2.1±1.86 in group one 4.19± 2.01 in group two, and 4.01± 2.21 in group three. This study showed statistically significant difference between group one and the other two groups regarding right atrial free wall strain and strain rate, septal wall strain and strain rate, mean right atrial strain and strain rate. These results were matched with the results of Ping Yan et al who showed significant difference between patients with IHD and control group regarding the RA strain and strain rate. The

difference between this study and the study of Ping Yan et al was that we studied the RA strain and strain rate with regard to the site of obstruction of the RCA, while they studied the RA strain and strain rate in ischemic heart disease patients who have mild or severe CAD without relating it to RCA lesion site ^[18].

Conclusion

The RA systolic function was found to be significantly impaired in patients with proximal RCA lesion as compared to patients with distal RCA lesion. These findings may have therapeutic implications in the management of patients with right ventricular infarction.

Limitations of the study

Few patients were included in the present study. Another study with larger number of patients is further required to validate the data.

References

1. Bonow R, Bacharach S, Green M, Kent K, Rosing D, Impaired left ventricular diastolic filling in patients with coronary artery disease: assessment with radionuclide angiography. *Circulation* 1981; 64: 315–23.
2. lee K, Blann A, Lip G. Impaired tissue Doppler diastolic function in patients with coronary artery disease: relationship to endothelial damage/dysfunction and platelet activation. *Am Heart J* 2005;150: 756–76,
3. Russo C, Jin Z, Homma S, Rundek T, Elkind M. Left atrial minimum volume and reservoir function as correlates of left ventricular diastolic function: impact of left ventricular systolic function. *Heart* 2012; 98: 813–20.
4. Perk G, Kronzon I. Non-Doppler two dimensional strain imaging for evaluation of coronary artery disease. *Echocardiography* 2009; 26: 299–30.
5. Kimura K, Takenaka K, Pan X, Ebihara A, Uno K. Prediction of coronary artery stenosis using strain imaging diastolic index at rest in patients with preserved ejection fraction. *J Cardiol* 2011 ;57:311-5.
6. Kataoka T, Kawai H, Okada M. The usefulness of left atrial strain and strain rate indices for evaluating left atrial reservoir and booster pump function in patients with left ventricular dysfunction. *J Am Soc Echocardiogr* 2007;20:609.
7. Yu C , Fung J , Zhang Q, Kum L, Lin H, Yip G, Wang M, Sanderson J. Tissue Doppler echocardiographic evidence of atrial mechanical dysfunction in coronary artery disease. *Int J Cardiol.* 2005;105:178-85.
8. Patel DA, MD, Lavie CJ, Milani RV, Shah S, and Gilliland Y. Clinical Implications of Left Atrial Enlargement: A Review. *Ochsner J.* 2009 Winter; 9(4): 191–196.
9. Ebtia M, Murphy D, Gin K, Lee P , Jue J, Nair P, Mayo J, Barnes M, Thompson D, Tsang T. Best Method for Right Atrial Volume Assessment by Two-Dimensional Echocardiography: Validation with Magnetic Resonance Imaging Echocardiography. 2015;32:734-9.
10. Mosteller R. Simplified Calculation of Body Surface Area. *N Engl J Med.* 1987;317:1098.
11. Di Salvo G, Caso P, Lo Piccolo R, Fusco A, Martiniello A, Russo M, D'Onofrio A, Severino S, Calabró P, Pacileo G, Mininni N, Calabró R. Atrial myocardial deformation properties predict maintenance of sinus rhythm after external cardioversion of recent-onset lone atrial fibrillation: a color Doppler myocardial imaging and transthoracic and transesophageal echocardiographic study. *Circulation* 2005;112: 387–95
12. Zhang Q, Yip W, and Yu M. Approaching regional left atrial function by tissue

- Doppler velocity and strain imaging. *Europace* 2008; 10: iii62–iii69.
13. Caso P, Ancona R, Di Salvo G, Comenale S, Macrino M, Di Palma V, D'Andrea A, Martiniello A, Severino S, Calabrò R. Atrial reservoir function by strain rate imaging in asymptomatic mitral stenosis: prognostic value at 3 year follow-up *European Journal of Echocardiography* 2009; 10:753–59.
 14. Mitchell J, Gilmore J, Sarnoff S .The transport function of the atrium. Factors influencing the relation between mean left atrial pressure and left ventricular end diastolic pressure. *Am J Cardiol* 1962;9: 237–47.
 15. Hoit B, Gabel M: Influence of left ventricular dysfunction on the role of atrial contraction: Echocardiographic hemodynamic study in dogs. *J Am Coll Cardiol*2000;36:1713–19.
 16. Rai AB, Lima E, Munir F, Khan AF, Waqas A, Bughio S, et al. Speckle Tracking Echocardiography of the Right Atrium: The Neglected Chamber. *Clin. Cardiol.* 2015; 38: (11) 692–697.
 17. Shinomiya H, Fukuda N, Takeichi N, Soeki T, Shinohara H, Yui Y, et al: Echocardiographic assessment of right atrial function in patients with myocardial infarction with reference to obstructive lesions of the coronary arteries. *Jpn Circ J.* 1998;62:393-398.
 18. Yan P, Sun B, Shi H, Zhu W, Zhou Q, Jiang Y et al: Left Atrial and Right Atrial Deformation in Patients with Coronary Artery Disease: A Velocity Vector Imaging Based Study. *journal pone.* 2012; 7:51-204.