

AN ECHOCARDIOGRAPHIC ASSESSMENT OF RIGHT VENTRICULAR FUNCTION IN INFERIOR WALL MYOCARDIAL INFARCTION UNDERGOING PRIMARY PTCA VS. PTCA WITHIN ONE MONTH OF INDEX EVENT- A FOLLOW-UP STUDY

Narasimha Pai D¹, Yogesh Kharche², Syed Waleem Pasha³, K. Padmanabha Kamath⁴, R. L. Kamath⁵, Chaithra Nayak⁶, Francis N. P. Monteiro⁷

¹Associate Professor, Department of Cardiology and Interventional Cardiologist, Kasturba Medical College, Affiliated to MAHE, Mangalore, Karnataka, India.

²Resident, Department of Cardiology, Kasturba Medical College, Affiliated to MAHE, Mangalore, Karnataka, India.

³Resident, Department of Cardiology, Kasturba Medical College, Affiliated to MAHE, Mangalore, Karnataka, India.

⁴Professor & H.O.D, Department of Cardiology & Interventional Cardiology, Kasturba Medical College, Ambedkar Circle (Affiliated to MAHE), Mangalore, India.

⁵Professor, Department of Cardiology, Kasturba Medical College, Affiliated to MAHE, Mangalore, Karnataka, India.

⁶Assistant Professor, Department of Cardiology, Kasturba Medical College, Affiliated to MAHE, Mangalore, Karnataka, India.

⁷Professor, Department of Forensic Medicine and Toxicology, A. J. Institute of Medical Sciences, Affiliated to Rajiv Gandhi University of Health Sciences, Mangalore, Karnataka, India.

ABSTRACT

BACKGROUND

Risk of shock, arrhythmia and death due to Inferior Wall Myocardial Infarction (IWMI) is higher in the presence of Right Ventricular Myocardial Infarction (RVMI). RVMI along with IWMI (relative risk 3.0) usually results from occlusion of dominant Right Coronary Artery (RCA). Electrocardiogram (ECG) frequently fails to predict proximal RCA as infarct related artery. ECG changes are brief and disappear within 10 hours in 48% of cases. Therefore, its utility reduces in cases of late presentations. There is lack of literature validating usefulness of various echocardiographic parameters in assessing RV function after successful revascularisation procedures in patients presenting with acute IWMI.

Aim: This research intends to assess right ventricle function by Tricuspid Annular Plane Systolic Excursion (TAPSE) and MPI by pulsed TDI in patients with acute IWMI after primary PTCA at discharge, 3 months and 6 months.

MATERIALS AND METHODS

This prospective cohort study was undertaken in the coronary care unit of the Dept. of Cardiology, Kasturba Medical College, Mangalore from September 2015 to October 2016 with first episode of acute inferior wall myocardial infarction and within one month of index event.

RESULTS

Our study group comprised of 84 patients, 60 (71.4%) males and 24 (28.6%) females. Predominantly, males were noted in the age group between 61-70 years (35.7%) and females in the age group between 51-60 years (28.6%). Mean age in Group 1 was 62.4±9.34 years and in Group 2 was 58±11.8 years 54 (64.3%). In our study, mean TAPSE measurement was significantly lower at the time of discharge in individuals with first episode of acute IWMI (14.98±1.33).

CONCLUSION

The results of this study indicate that acute IWMI affecting the right ventricle seriously impairs RV systolic function with significant improvement at 3 months and 6 months follow-up after the acute event with successful revascularisation. Echocardiographic assessment of RV function (MPI and TAPSE) showed a significant difference between groups with acute IWMI and recent IWMI. In IWMI patients, significant increase in TAPSE values were observed post reperfusion. Reperfusion therapy, especially primary PCI restores the RV systolic function more rapidly in patients with acute IWMI. Reperfusion therapy in patients presenting within one month of index event also restore the right ventricular systolic function, particularly in those who received thrombolysis.

KEY WORDS

Arrhythmia; Circulation; Physiology; Ventricular Interdependence.

HOW TO CITE THIS ARTICLE: Pai ND, Kharche Y, Pasha SW, et al. An echocardiographic assessment of right ventricular function in inferior wall myocardial infarction undergoing primary PTCA vs. PTCA within one month of index event- a follow-up study. J. Evolution Med. Dent. Sci. 2018;7(34):3780-3785, DOI: 10.14260/jemds/2018/848

'Financial or Other Competing Interest': None.
Submission 03-07-2018, Peer Review 01-08-2018,
Acceptance 09-08-2018, Published 20-08-2018.

Corresponding Author:

Dr. Yogesh Kharche,
Department of Cardiology,
Kasturba Medical College,
Mangalore, Karnataka, India.

E-mail: narasimhapai@yahoo.com

DOI: 10.14260/jemds/2018/848



BACKGROUND

The knowledge of the normal Right Ventricular (RV) physiology was lacking for years after the mechanics of Left Ventricular (LV) was first described,¹ not least owing to early reports of elegant animal models showing that cardiac output was maintained in electrically isolated RV in otherwise normal hearts² or when replacing the RV with a non-contracting material.³ The concept of 'ventricular interdependence' was introduced as the LV contribution of the RV stroke work, which was estimated to be 30%. When

the pressure-volume relationship of the RV was first determined in 1988,⁴ the basis for improving our understanding of RV physiology improved and the significance of the RV in the circulatory system was increasingly being appreciated. The RV importance in the normal circulation has been neglected for many years, indeed this part of the heart was referred to as 'the forgotten chamber' in the review of Rigolin et al in 1994.⁵ Findings in various diseases it seems that the dysfunction of the ventricles does have independent clinical or prognostic importance.⁶⁻⁹

Risk of shock, arrhythmia and death in inferior wall MI is higher in the presence of RVMI. RV infarction in inferior wall MI (relative risk 3.0) usually results from occlusion of dominant RCA.^{10,11,12} ECG frequently fails to predict proximal RCA as infarct related artery. ECG changes are momentary and vanish within 10 hours in 48% of cases. Therefore, its utility diminishes with late presentations.

There is dearth of literature validating usefulness of various echocardiographic parameters in assessing RV function after successful revascularisation procedures in patients presenting with acute IWMI.

RV due to its complex geometry and difficulty in defining the endocardial borders are limited by the conventional measurements of area and volume.^{13,14} Tissue Doppler indices like Myocardial Performance Index (MPI) and many more other indices have proven role in assessing global RV function.^{15,16,17,18,19,20}

The objective of this study is to evaluate right ventricle function by Tricuspid Annular Plane Systolic Excursion (TAPSE) and Myocardial Performance Index (MPI) by pulsed TDI in patients with acute IWMI after primary PTCA at discharge, 3 months and 6 months; To evaluate right ventricle function by Tricuspid Annular Plane Systolic Excursion (TAPSE) and Myocardial Performance Index (MPI) by pulsed TDI in patients within one month of index event after undergoing successful revascularisation at baseline, discharge, 3 months and 6 months.

MATERIALS AND METHODS

This is a prospective cohort study conducted at Coronary Care Unit of the Dept. of Cardiology, Kasturba Medical College, Mangalore. Study population consists of patients admitted to Coronary Care Unit from October 2015 to October 2016 with first episode of acute IWMI and within one month of index event. Our study groups comprised of 84 patients. Sample size was taken as per our convenience.

By using convenient sampling and applying the eligibility criteria during the study period, 42 individuals with first episode of acute IWMI and 42 individuals with one month of index event (with or without thrombolysis) were included in the study.

Inclusion Criteria

1. Patients with acute inferior wall myocardial infarction undergoing primary PCI.
2. Patients undergoing PCI within one month of index event (with or without thrombolysis).

Exclusion Criteria

1. Pulmonary hypertension with RV systolic pressure by Echo > 40 mmHg.

2. Chronic obstructive pulmonary disease.
3. Pulmonary embolism.
4. Left bundle branch block.
5. Atrial fibrillation.
6. Poor Echo window.
7. Valvular heart disease more than mild as per ACC/ AHA criteria.

Patients with acute inferior wall myocardial infarction undergoing primary PCI and patients undergoing PCI within one month of index event (with or without thrombolysis) were included in the study.

Patients with pulmonary hypertension with RV systolic pressure by Echo > 40 mmHg; chronic obstructive pulmonary disease; pulmonary embolism; left bundle branch block; atrial fibrillation; poor echo window and valvular heart disease more than mild as per ACC/ AHA criteria were excluded from the study.

Acute IWMI is defined as ischaemic cardiac pain lasting more than 30 mins, characteristic ST-segment elevation of 0.1 mV in two or more inferior leads (II, III, aVF) and CK-MB elevation more than twice the upper reference limit. ECG evidence of RV infarction is defined as ST segment elevation of 0.1 mV in V4R in ECG taken within 6 hours of onset of symptoms.

The old IWMI would be defined by the absence of ST segment elevation in inferior leads. In patients undergoing early coronary recanalization, the development of q or Q waves may not be observed. In such cases, observation of symmetrical negative T waves in leads II, III and aVF may suggest the diagnosis of old MI.

In our study, all patients underwent coronary angiogram which was done to identify the culprit lesion on the basis of the infarct location on the admission. DES was used after performing pre-balloon dilatation for indicated cases and then analysed to determine the extent of flow, which was graded according to the Thrombolysis in Myocardial Infarction (TIMI) classification. All cases that achieved TIMI III flow were included in the study. Individuals with first episode of acute IWMI patients underwent primary PTCA immediately after admission.

An echocardiographic assessment of RV function by TAPSE and MPI by TDI was performed after successful revascularization procedure at discharge for patients with acute IWMI and at admission (baseline) in patients with one month of index event in these two groups at discharge, 3 months and 6 months. Our aim was to evaluate RV function by TAPSE, MPI at different time interval and compare.

All two-dimensional, M-mode and conventional Doppler echocardiographic measurements were performed according to guidelines of American Society of Echocardiography (ASE). All measurements were repeated thrice, and mean values were taken. There are various methods to assess RV function. In this present study, we are using TAPSE and MPI by tissue Doppler.²¹

Continuous data will be expressed as Mean±Standard Deviation. Categorical data will be expressed as percentage or exact frequencies. Comparison between the groups of continuous data will be done using Student's t-test. Comparison of repeated measurement will be done by repeated measures ANOVA and post-hoc analysis by Bonferroni test. P value less than 0.05 will be considered to

be statistically significant. A statistical package SPSS version 17.0 was used for data analysis.

RESULTS

Our study groups comprised of 84 patients, 60 males and 24 females. All patients had proximal RCA stenosis. No statistically significant difference was found between groups with regard to baseline variables like age, sex, type 2 diabetes mellitus or hypertension. Predominantly, males of age group between 61-70 vs. (35.7%) and females of the age group 51-60 years (28.6%) were admitted with inferior wall myocardial infarction. Out of 84 patients, 47.6% had past history of type 2 diabetes mellitus. Of the 84 patients, 43% patients had past history of hypertension.

There was a statistically significant difference in the mean ejection fraction of the patients between the two groups with p-value of 0.006 (Table 1).

	Total No.	Mean	Standard Deviation	Median	P value
Individuals with first episode of acute IWMI	42	54.8167	1.12725	54.8	0.006
Individuals with one month of index event	42	53.9952	1.53368	54.5	
Total	84	54.4060	1.40012	54.7	

Table 1. Distribution of Ejection Fraction

All 42 individuals with first episode of acute IWMI showed statistically significant increase in the TAPSE at different time intervals with p-value less than 0.05. Analysis was done with repeated measures ANOVA as described in Table 2.

TAPSE	N	Mean	Standard Deviation	95% Confidence Interval for Mean		ANOVA F	P
				Lower Bound	Upper Bound		
Discharge	42	14.98	1.334	14.56	15.39	449.918	0.000 HS
3 months	42	17.48	0.994	17.17	17.79		
6 months	42	19.93	1.404	19.49	20.37		
Table 2. Individuals with First Episode of Acute IWMI: Evaluation of TAPSE at different Time Intervals							

In individuals with first episode of acute IWMI, post-hoc analysis using Bonferroni test revealed that TAPSE measurements between discharge and 3 months (14.98±1.33 vs. 17.48±0.994) with mean difference -2.5 was statistically significant with p-value less than 0.000. TAPSE measurements between discharge and 6 months (14.98±1.33 vs. 19.93±1.404) with mean difference -4.952 was statistically significant (p < 0.000). TAPSE measurements between 3 and 6 months (17.48±0.994 vs. 19.93±1.404) with mean difference -2.452 was statistically significant (p<0.000). TAPSE showed statistically significant difference among different time intervals. Mean difference among measurement of TAPSE was highest between discharge and six months interval.

All 42 individuals with one month of index event showed statistically significant increase in the TAPSE at different time

intervals (p < 0.05) when analysed by repeated measures ANOVA (Table 3).

TAPSE	N	Mean	Standard Deviation	95% Confidence Interval for Mean		ANOVA F	P
				Lower Bound	Upper Bound		
Baseline	42	14.45	1.109	14.11	14.80	118.336	0.000 HS
Discharge	42	14.86	1.095	14.52	15.20		
3 months	42	15.67	0.954	15.37	15.96		
6 months	42	16.52	1.018	16.21	16.84		
Table 3. Individuals with One Month of Index Event: Evaluation of TAPSE at different Time Intervals							

Applied test: ANOVA F.

In individuals with one month of index event, post-hoc analysis using Bonferroni test revealed that TAPSE between baseline and 6 months (14.45±1.109 vs. 16.52±1.018) with mean difference -2.071 was statistically significant with p-value less than 0.000.

Individuals with first episode of acute IWMI, all 42 patients showed statistically significant change in MPI measurement at different time intervals. Repeated measures ANOVA determined that mean TAPSE measurements differed statistically significantly between time intervals with p-value of 0.000 (Table 4). Mean MPI measurement were significantly higher at the time of discharge; however, it improved in follow-up at three months and six months. However, measurements on admission (baseline) were not taken in this group, as it was ethically not correct to delay reperfusion strategy.

MPI	N	Mean	Standard Deviation	95% Confidence Interval for Mean		ANOVA F	P
				Lower Bound	Upper Bound		
Discharge	42	0.7774	0.10010	0.7462	0.8086	259.494	0.000 HS
3 months	42	0.5445	0.4295	0.5311	0.5579		
6 months	42	0.4886	0.2901	0.4795	0.4976		
Table 4. Individuals with First Episode of Acute IWMI: Evaluation of MPI at different Time Intervals							

Applied test: ANOVA F.

Mean difference among measurement of MPI was highest between discharge and six months' interval. Post-hoc analysis using Bonferroni test revealed that MPI measurements between discharge and 3 months (0.7774±0.10010 vs. 0.5445±0.4295) with mean difference of 0.233 was statistically significant with p-value less than 0.000. MPI measurements between discharge and 6 months (0.7774±0.10010 vs. 0.4886±0.2901) with mean difference 0.289 was statistically significant with p-value less than 0.000. This was the highest mean difference among all-time intervals. MPI measurements between 3 months and 6 months (0.5445±0.4295 vs. 0.4886±0.2901) with mean difference of 0.056 was statistically significant (p < 0.000).

All 42 individuals with one month of index event showed statistically significant change in MPI measurement at different time intervals. Repeated measures ANOVA determined that mean TAPSE measurements differed

statistically significantly between time intervals with p-value of 0.000 (Table 5).

MPI	N	Mean	Std. Deviation	95% Confidence Interval for Mean		ANOVA F	P
				Lower bound	Upper bound		
Baseline	42	0.7833	0.09948	0.7523	0.8143	154.683	0.000 HS
Discharge	42	0.7136	0.09837	0.6829	0.7442		
3 months	42	0.6119	0.09711	0.5816	0.6422		
6 months	42	0.5455	0.08640	0.5186	0.5724		

Table 5. Individuals with One Month of Index Event: Evaluation of MPI at different Time Intervals

Applied test: ANOVA F.

Post-hoc analysis using Bonferroni test revealed that MPI measurements between baseline and 6 months (0.7833±0.09948 vs. 0.5455±0.08640) with mean difference of 0.238 was statistically significant with p-value less than 0.000. Mean difference among measurement of MPI was highest between baseline and six-month interval. Mean difference was lowest among measurement of MPI between baseline and discharge interval.

Our study results found that the mean change in individuals with first episode of acute IWMI had statistically higher values of TAPSE at 3 months (17.48±0.994) compared to individuals with one month of index event and at 3 months (15.67±0.954). No significant difference in mean TAPSE measurements at discharge between individuals with first episode of acute IWMI and individuals with one month of index event. Our study results also found that the mean change of TAPSE measurement in individuals with first episode of acute IWMI had statistically higher values at 6 months (19.93±1.404) compared to individuals with one month of index event at 6 months (16.52±1.018).

No significant difference in Mean TAPSE measurements between the individuals with first episode of acute IWMI and individuals with one month of index event at discharge. Significant differences in mean TAPSE measurements seen at 6-month interval between the individuals with first episode of acute IWMI and individuals with one month of index event.

DISCUSSION

Our study group comprised of 84 patients, 60 males and 24 females. Except three patients, all patients had proximal RCA stenosis. There was no statistically significant difference between groups with regard to baseline variables like age, sex, Body Mass Index (BMI), type 2 diabetes mellitus or hypertension. Known hypertensive (43%) and diabetic (47.6%) patients were included in the study. Compared to other studies with known diabetic patients, hypertensives were more.

In 42 individuals with first episode of acute IWMI showed statistically significant change in TAPSE measurement at different time intervals. TAPSE < 16 mm indicates RV systolic dysfunction according to ASE guidelines.²¹ In our study, mean TAPSE measurement was significantly lower at time of discharge in individuals with first episode of acute IWMI (14.98±1.33), which indicates that systolic function was impaired in IWMI patients with RV involvement. These results are in agreement with the study conducted by GN Rajesh et al²² (2012). However, in our study TAPSE improves

in follow-up at three months and six months. While it would have been more appropriate to compare with baseline TAPSE measurement, this was not practically feasible. Baseline TAPSE measurements were not taken in this group, as it was ethically not correct to delay reperfusion strategy. A statistically significant difference was documented among measurement of TAPSE between the different time intervals. Mean difference among measurement of TAPSE was highest between discharge and six-month interval. TAPSE measurements between discharge and 6 months was (14.98±1.33 vs. 19.93±1.404) with mean difference of -4.952.

In individuals with one month of index event, all 42 patients showed statistically significant change in TAPSE measurement at different time intervals, which were significantly lower at time of admission (baseline) and discharge. This implies that systolic function was impaired in IWMI patients with RV involvement. However, it improved during follow-up at six months.

Our study results found that the mean change in TAPSE of individuals with first episode of acute IWMI patients had statistically higher values at 3 months (17.48±0.994) compared to individuals with one month of index event (15.67±0.954). Both groups showed impaired systolic function in IWMI patients with RV involvement at discharge. Our study results also found that the mean change of TAPSE measurement in individuals with first episode of acute IWMI had statistically higher values at 6 months (19.93±1.404) compared to individuals with one month of index event at 6 months (16.52±1.018).

Between the discharge to 6 months' time interval in individuals with first episode of acute IWMI, patients had statistically significant higher value of mean change (-4.952) compared to individuals with one month of index event (-1.667) with p-value less than 0.0005. Utility of TAPSE in the diagnosis of RV infarction was established by several researches conducted in this field.^{23,24} In our study, both groups showed impaired systolic function in IWMI patient with RV involvement at discharge.

Individuals with one month of index event contains patients admitted within one month of index event, of which few received thrombolytic therapy and others did not as they presented out of window period. 22 patients out of 42 received thrombolysis at outside hospital. TAPSE measurement was abnormal in thrombolysis subgroup 95.5% (21 patients) on admission and discharge. At the end of six months, 68.2% (15 patients) showed improvement in TAPSE measurement in thrombolysis subgroup. In other subgroup TAPSE was abnormal in 100% (20 patients); however, only 10% (2 patients) showed improvement in TAPSE parameter at the end of six months.

Individuals with one month of index event had significantly reduced tricuspid annular motion and velocities with or without thrombolytic therapy. Significant increase in TAPSE values were observed in patients with thrombolytic therapy in individuals with one month of index event. Due to thrombolysis, some patency of infarct related artery must be established in this subgroup.

Mean MPI measurement was significantly higher at time of discharge in individuals with first episode of acute IWMI (0.7774±0.10010), which suggest that systolic function was impaired in IWMI patients with RV involvement. These results are in agreement with that reported by GN Rajesh et

al,²² (2012) who observed a significantly higher myocardial performance index by pulsed wave Doppler (MPI-PW) in patients with a proximal RCA lesion. However, our study shows improvement in follow-up at three months and six months. Measurements on admission (baseline) were not taken in this group as they delay reperfusion therapy. Mean difference among measurement of MPI was highest between discharge and six-month interval. MPI measurements between discharge and 6 months (0.7774±0.10010 vs. 0.4886±2.901) with mean difference was 0.289. The results of this study indicate that in the case of acute inferior wall myocardial infarction affecting the right ventricle, RV systolic function is seriously impaired with significant improvement 6 months after the acute event, although this improvement reach normal values at 3 months follow-up in individuals with first episode of acute IWMI.

In individuals with one month of index event, all 42 patients showed statistically significant change in MPI measurement at different time intervals. Mean MPI measurement were significantly higher at time of admission (baseline) (0.7833±0.09948) and discharge and three months follow-up which means that systolic function was impaired in IWMI patients with RV involvement. However, it improved in follow-up at six months. MPI measurements between baseline and 6 months (0.7833±0.09948 vs. 0.5455±0.08640) with mean difference of 0.238 was highest. RV function recovered in individuals with one month of index event, also during 6 months after the PTCA. Amongst cardiac ventricles, there is a difference between right and left ventricle regarding their vulnerability to ischaemia and reperfusion. In an ideal physiological state, the oxygen demand of right ventricular myocardium is lower than the oxygen demand of left ventricular myocardium. This is because of lower vascular resistance in the pulmonary circulation when compared to the systemic circulation. In addition, the right ventricle receives transmural and endocardial perfusion during both systole and diastole,^{23,25} because of the thinner free wall and lesser intracavitary pressure. Therefore, even in the absence of coronary flow, right ventricular myocardium continues to receive significant amount of oxygen and nutrients resulting in “stunning” rather than cell death.²⁶

In our study, individuals with one month of index event contains patients presenting within month of index event. These patients have stunned myocardium. Hence, RV function recovery is late despite of reperfusion.

Comparison of MPI between individuals with first episode of acute IWMI and individuals with one month of index event at 3 months' and 6 months' interval shows significant differences. Significant differences in mean MPI measurements between the individuals with first episode of acute IWMI and individuals with one month of index event seen at discharge, three months and six months interval. Our study results found that individuals with first episode of acute IWMI had lower values of MPI statistically significant at 3 months (0.5445 +/- 0.04295) compared to individuals with one month of index event at 3 months (0.6119 +/- 0.09711). It shows that RV systolic function was not improved in individuals with one month of index event at the end of 3 months of follow-up as compared to individuals with first episode of acute IWMI as RV myocardium is in stunning phase. RV systolic function was normal at the end of 3 months follow-up in individuals with first episode of acute IWMI.

This study demonstrated that RV function was significantly reduced in IWMI patients. Our study confirms the great recovery potential of RV after an ischaemic insult: systolic function begins to improve after reperfusion and normalise within 3 months. Therefore, successful reperfusion in acute IWMI can result in quick improvement of RV performance and thus of clinical outcome. In our opinion, the identification of patients with impaired RV function may add important information that is helpful for proper risk stratification and choice of treatment.

CONCLUSION

- In case of acute IWMI affecting the right ventricle, RV systolic function is seriously impaired with significant improvement occurring at 3 months and 6 months follow-up after the acute event with successful revascularisation.
- Significant improvement in RV systolic function at follow-up may represent a possible recovery of stunned myocardium.
- Reperfusion therapy, especially primary PCI restores the RV systolic function more rapidly in patients with acute IWMI. Reperfusion therapy in patients presenting within one month of index event also restore the RV systolic function, particularly in those who received thrombolysis.
- Our study confirms the great recovery potential of the RV after an ischaemic insult. Its systolic function begins to improve after reperfusion and normalises within 3 months. Therefore, successful reperfusion in acute IWMI can result in quick improvement of RV performance and thus of clinical outcome.

REFERENCES

- [1] Sheehan F, Redington A. The right ventricle: anatomy, physiology and clinical imaging. *Heart* 2008;94(11):1510-5.
- [2] Damiano RJ Jr, La Follette P Jr, Cox JL, et al. Significant left ventricular contribution to right ventricular systolic function. *Am J Physiol* 1991;261(5 Pt 2):H1514-24.
- [3] Hoffman D, Sisto D, Frater RW, et al. Left-to-right ventricular interaction with a non-contracting right ventricle. *J Thorac Cardiovasc Surg* 1994;107(6):1496-502.
- [4] Redington AN, Gray HH, Hodson ME, et al. Characterisation of the normal right ventricular pressure-volume relation by biplane angiography and simultaneous micromanometer pressure measurements. *Br Heart J* 1988;59(1):23-30.
- [5] Rigolin VH, Robiolio PA, Wilson JS, et al. The forgotten chamber: the importance of the right ventricle. *Cathet Cardiovasc Diagn* 1995;35(1):18-28.
- [6] De Groote P, Millaire A, Foucher-Hossein C, et al. Right ventricular ejection fraction is an independent predictor of survival in patients with moderate heart failure. *J Am Coll Cardiol* 1998;32(4):948-54.
- [7] Gavazzi A, Berzuini C, Campana C, et al. Value of right ventricular ejection fraction in predicting short-term

- prognosis of patients with severe chronic heart failure. *J Heart Lung Transplant* 1997;16(7):774-85.
- [8] Burgess MI, Mogulkoc N, Bright-Thomas RJ, et al. Comparison of echocardiographic markers of right ventricular function in determining prognosis in chronic pulmonary disease. *J Am Soc Echocardiogr* 2002;15(6):633-9.
- [9] Mehta SR, Eikelboom JW, Natarajan MK, et al. Impact of right ventricular involvement on mortality and morbidity in patients with inferior myocardial infarction. *J Am Coll Cardiol* 2001;37(1):37-43.
- [10] Zehender M, Kasper W, Kauder E, et al. Eligibility for and benefit of thrombolytic therapy in inferior myocardial infarction: focus on the prognostic importance of right ventricular infarction. *J Am Coll Cardiol* 1994;24(2):362-9.
- [11] Erhardt LR, Sjogren A, Wahlberg I. Single right-sided precordial lead in the diagnosis of right ventricular involvement in inferior myocardial infarction. *Am Heart J* 1976;91(5):571-6.
- [12] Braat SH, Brugada P, de Zwaan C, et al. Value of electrocardiogram in diagnosing right ventricular involvement in patients with an acute inferior wall myocardial infarction. *Br Heart J* 1983;49(4):368-72.
- [13] Haddad F, Hunt SA, Rosenthal DN, et al. Right ventricular function in cardiovascular disease, part I: anatomy, physiology, aging and functional assessment of the right ventricle. *Circulation* 2008;117(11):1436-48.
- [14] Jurcut R, Giusca S, La Gerche A, et al. The echocardiographic assessment of the right ventricle: What to do in 2010. *Eur J Echocardiogr* 2010;11(2):81-96.
- [15] Jiang L. Right ventricle. In: Weyman AE, edr. *Principles and practice of echocardiography*. Baltimore: Lippincott Williams and Wilkins 1994: p. 901-21.
- [16] Anderson RH, Smerup M, Sanchez-Quintana D, et al. The three-dimensional arrangement of the myocytes in the ventricular walls. *Clin Anat* 2009;22(1):64-76.
- [17] Leather HA, Ama' R, Missant C, et al. Longitudinal but not circumferential deformation reflects global contractile function in the right ventricle with open pericardium. *Am J Physiol Heart Circ Physiol* 2006;290(6):H2369-75.
- [18] Tei C, Dujardin KS, Hodge DO, et al. Doppler echocardiographic index for assessment of global right ventricular function. *J Am Soc Echocardiogr* 1996;9(6):838-47.
- [19] Chockalingam A, Gnanavelu G, Alagesan R, et al. Myocardial performance index in evaluation of acute right ventricular myocardial infarction. *Echocardiography* 2004;21(6):487-94.
- [20] Ozdemir K, Altunkeser BB, Icli A, et al. New parameters in identification of right ventricular myocardial infarction and proximal right coronary artery lesion. *Chest* 2003;124(1):219-26.
- [21] Rudski LG, Lai WW, Afilalo J, et al. Guidelines for the echocardiographic assessment of the right heart in adults: a report from the American Society of Echocardiography endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology and the Canadian Society of Echocardiography. *J Am Soc Echocardiogr* 2010;23(7):685-713.
- [22] Rajesh GN, Raju D, Nandan D, et al. Echocardiographic assessment of right ventricular function in inferior wall myocardial infarction and angiographic correlation to proximal right coronary artery stenosis. *Indian Heart Journal* 2013;65(5):522-8.
- [23] Alam M, Wardell J, Andersson E, et al. Right ventricular function in patients with first myocardial infarction: assessment by tricuspid annular motion and tricuspid annular velocity. *Am Heart J* 2000;139(4):710-5.
- [24] Kloner RA, Bolli R, Marban E, et al. Medical and cellular implications of stunning, hibernation and preconditioning: an NHLBI workshop. *Circulation* 1998;97(18):1848-67.
- [25] Samad BA, Alam M, Jensen-Urstad K. Prognostic impact of right ventricular involvement as assessed by tricuspid annular motion in patients with acute myocardial infarction. *Am J Cardiol* 2002;90(7):778-81.
- [26] Kinch JW, Ryan TJ. Right ventricular infarction. *N Engl J Med* 1994;330(17):1211-7.