Exp Biomed Res 2022; 5(2): 194-203
Doi: 10.30714/j-ebr.2022275816

Experimental Biomedical Research Original article

The combined S velocity achieved from tricuspid annulus and pulmonary annulus with tissue Doppler imaging could predict the proximal right coronary artery occlusion in patients with inferior myocardial infarction

Emrah Acar[1], Neryan Ozgul[2], Ibrahim Donmez[1], Osman Yasin Yalcin[1], Oguz Kayabas[3], Sait Alan[1], Ibrahim Akin Izgi[1]

[1]*Department of Cardiology, Bolu Abant Izzet Baysal University, Medical Faculty, Bolu, Turkey*
[2]*Department of Cardiology, Kastamonu Research and Training Hospital, Kastamonu, Turkey*
[3]*Department of Cardiology, Cankiri State Hospital, Cankiri, Turkey*

ABSTRACT

Aim: To investigate if combined S velocity (CSV) calculated from tricuspid annulus and pulmonary annulus with tissue Doppler imaging in individuals with acute inferior myocardial infarction were linked to proximal RCA lesions.
Methods: The study comprised 48 patient who had been diagnosed with acute inferior myocardial infarction and had culprit lesions in the right coronary artery. The RCA occlusion in Group A was proximal to the right ventricular branch, while the RCA occlusion in Group B was distant to the RV branch. The combined S velocity was tested, as well as other echocardiographic parameters.
Results: In terms of metrics indicating right ventricular function, there were substantial disparities between the groups. A favorable association was established in the univariate correlation analysis between CSV and tissue Doppler imaging derived tricuspid annulus systolic velocity (St), pulmonary annulus motion velocity evaluated by TDI (PAMVUT), RV tricuspid annular plane systolic excursion (TAPSE), and fractional area change (FAC). CSV was identified as an independent predictor of proximal RCA occlusion in a multivariate logistic regression test. In the ROC analysis, CSV<18.3 cm/s and PAMVUT<8.6 cm/s indicated proximal RCA occlusion with 83 percent sensitivity and 71 percent specificity (AUC=0.83, *p*<0.001), and 85 percent sensitivity and 71 percent specificity (AUC=0.81, *p*<0.001), respectively.
Conclusion: CSV measurements were revealed to be an important predictor of proximal RCA occlusions in this investigation.

Key words: Doppler echocardiography, inferior myocard infarction, pulsed-wave tissue Doppler, right coronary artery, right ventricular function.

Dr. Emrah Acar, Department of Cardiology, Bolu Abant Izzet Baysal University, Medical Faculty, Bolu, Turkey.
E- mail: dreacar44@hotmail.com
Received: 2021-07-18 / Revisions: 2022-01-31
Accepted: 2022-02-08 / Published: 2022-03-15

Introduction

Right ventricular myocardial infarction is one of the most prevalent causes of right ventricular dysfunction (RVMI). Over half of those who had an inferior infarct also had right ventricular involvement, according to research [1]. Patients who experienced a right ventricular and inferior infarction were more likely to experience bradycardia, severe hypotension, and mortality than those who did not [2]. RVMI is most commonly associated with proximal occlusion of a dominant right coronary artery in individuals with inferior myocardial infarction [3]. Electrocardiograms (EKGs) typically reveal that predicting proximal RCA stenosis as an infarct-related artery is difficult [4].

Furthermore, EKG changes are transient, disappearing in roughly half of instances within 10 hours, making it inaccurate. Echocardiography is the most often used technique in everyday life to assess RV shape and function [5]. This is owing to factors such as inexpensive cost, non-invasive nature, and availability in almost all cardiology clinics. In individuals with acute inferior myocardial infarction, echocardiographic testing has been used to predict proximal RCA and RV involvement [6-10].

Parameters based mostly on the RV's longitudinal activities were examined while assessing RV functioning. TAPSE (tricuspid annular plane systolic excursion), tissue Doppler evaluation of tricuspid annular tissue velocity (St), and RV free wall longitudinal strain measured from the apical four chambers are the most widely utilized metrics [11]. The anatomical anatomy of the RV cannot be appraised uniformly; nonetheless, discrepancies must be considered when evaluating RV functioning. From an anatomical aspect, the RV is formed like a triangle or a pyramid. As a result, only one corner of this triangle is covered by the tricuspid annulus-based properties that have been assessed. Furthermore, ventricular function can differ according on the location, direction, and severity of the sickness, and may not be equal in all locations. As a result, these methods are unlikely to be suitable for functional evaluation. In this context, investigations show that right ventricular outflow tract (RVOT) systolic movements are crucial for RV function [12-15]. RVOT systolic excursion (RVOT-SE) values can identify whether the causal arterial blockage in acute inferior MI patients is in the proximal RCA, according to a study [12]. According to papers [13-15], pulmonary annulus motion velocity evaluated by TDI (PAMVUT) and tissue Doppler imaging (TDI) velocities recorded at the region where the pulmonary annulus enters the free RV wall are another useful tool for determining RVOT functions. We hypothesized that by combining St with PAMVUT, we may obtain the combined S velocity (CSV), a measure that better characterizes RV functions.

Materials and methods

Design and patients characteristics

The study was designed as a non-randomized, single-center observational study. Between August 2020 and April 2021, 92 patients were referred to us for revascularization with primary percutaneous coronary intervention for acute inferior myocardial infarction. The researchers looked at all of the patients in chronological order. Twenty-four individuals were ruled out because of culprit lesions in the circumflex artery (CX); three patients were ruled out because of blockage in the left anterior descending artery (LAD); 14 patients were ruled out because of poor picture quality; and three patients were ruled out for other reasons. After the cases were eliminated, there were 48 patients who matched the following criteria: age 18 or older, start of symptoms within 12 hours, ST-segment elevation of at least 1 mm in the inferior leads of the ECG, and coronary angiography demonstrating RCA blockage. Atrial fibrillation, atrioventricular block, ventricular arrhythmias, cardiogenic shock or hemodynamic instability, concomitant moderate to severe valvular pathology, active infection, liver and kidney failures, severe pulmonary illness, or a history of pulmonary hypertension were all excluded from the study.

CX dominance in the coronary artery system was ruled out, as was greater than 50% stenosis in the LAD and CX arteries, as well as a history of PCI and MI. Patients with poor echogenicity were also eliminated. Patients were given sufficient treatment as soon as an inferior MI was diagnosed, according to the guideline, and PCI was utilized to revascularize them afterwards, according to the guideline [16]. The RCA occlusion in Group A was proximal to the RV branch, whereas the RCA occlusion in Group B was distant to the RV branch.

The local institutional ethics committee gave its approval to the investigation. All participants signed informed consent forms, both verbally and in writing.

Echocardiography

The Vivid 7 machine was used to perform all echocardiographic exams 24 hours after PCI (GE Vingmed Ultrasound AS, Horten, Norway). At the end of the exhale phase, three cardiac cycles were recorded. All of the data was sent to a workstation for processing off-line (EchoPAC PC; GE Vingmed Ultrasound AS). Traditional two-dimensional (2D) echocardiographic examinations were carried out using the methodology outlined in a publication published by the American Society of Echocardiography [17]. The length of the left atrium (LA) and ventricle (LV) was measured. The bi-plane Simpsons technique was used to compute the LV ejection fraction (EF). The RV's fractional area change (FAC) was computed using the percent area change in the apical four-chamber image at end-systole and end-diastole at end-systole and end-diastole. TAPSE was calculated in M mode to determine the longitudinally crossing the tricuspid annular plane and parallel to the lateral wall systolic displacement of the right ventricle. The E/A ratio was determined using pulsed-wave Doppler imaging of the mitral inflow profile, which revealed ventricular filling velocities in early (E) and late (A) waves [19]. The systolic (Sm), early diastolic (em), and late diastolic (am) velocities of the myocardium were all assessed using a TDI sample volume positioned at the septal and lateral mitral annuli. After that, the E/e ratio was created. The TDI method was used to determine the St, et, and velocities by placing a sample volume on the free wall of the right ventricle. TDI was used to calculate RV MPI from the lateral tricuspid annulus. The ejection time was calculated using Sm's

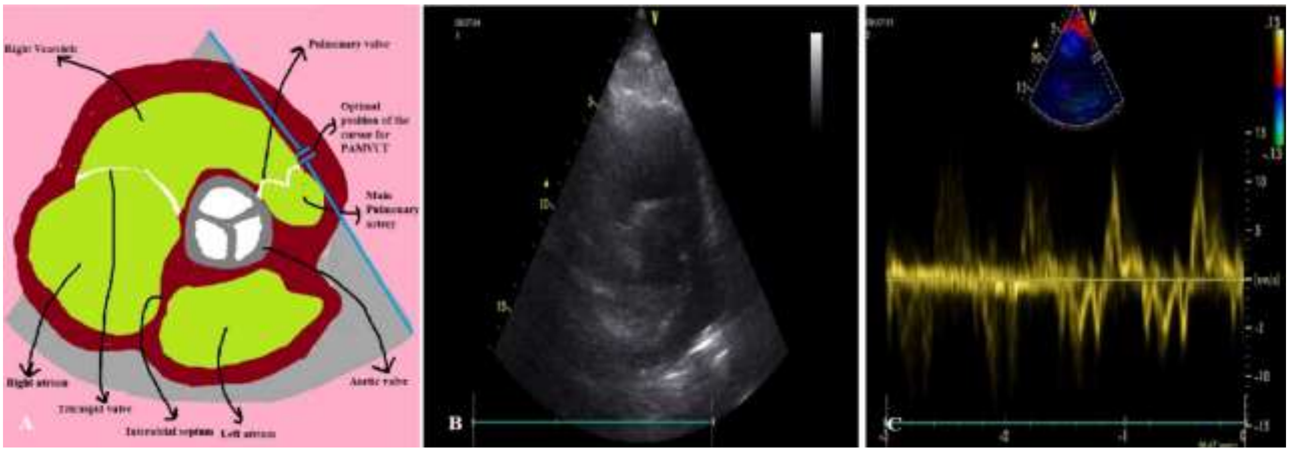

Figure 1. The measuring of PAMVUT. **A)** Optimal location of PW's cursor for PAMVUT. **B)** The RVOT's long axis view focused on pulmonary annulus. **C)** TDI-Doppler imaging of the lateral side of the pulmonary annulus. *TDI: Tissue Doppler imaging. PAMVUT: pulmonary annulus motion velocity evaluated by TDI.*

duration (ET). The duration between the end of the Sm and the start of the Em was characterized as the isovolumetric relaxation time (IVRT). The isovolumetric contraction time was defined as the period between the commencement of Am and the start of Sm (IVCT). [(IVRT + IVCT)/ET] The MPI was determined by dividing the ratio of isovolumetric times by ET (11). The PAMVUT was estimated using TDI in the RVOT's long-axis picture (Figure 1a-c). On the free wall side of the RV's pulmonary annulus, a sample volume was established with a fixed length of 5.0mm. PAMVUT, a CSV value finder, was integrated to the St.

Bolu Abant İzzet Baysal University ethics committee approved the study protocol (Approval ID: 2021/214). Written informed consent was obtained from each subject following a detailed explanation of the objectives and protocol of the study which was conducted in accordance with the ethical principles stated in the “Declaration of Helsinki” and approved by the institutional ethics committee.

Statistical analysis

The data is represented as percentages, mean, median (25th-75th percentile), and standard deviation. If each variable had a normal distribution, the Kolmogorov-Smirnov test was used to determine this. To compare groups with non-normally distributed data, nonparametric tests were utilized. The Mann-Whitney U test or the Students t-test were used to compare continuous variables. The distributions of categorical data were examined using Chi-square and Fisher's exact tests. Pearson's correlation analysis was used to compare the correlation between the continuous variables. For the multivariate analysis, significant parameters from the univariate analysis ($p<0.05$) were chosen. To investigate independent predictors of proximal RCA blockage, we conducted multiple logistic regression analyses. Receiver operator characteristic (ROC) curves were then used to assess the diagnostic efficiency of each parameter. The best cut-off values for diagnosing proximal RCA blockage have been identified. Statistical significance was defined as a p-value of less than 0.05. For all statistical studies, SPSS v16.0 was utilized (SPSS, Inc., Chicago, IL).

Results

The study enlisted the participation of 48 patients. Twenty-four people in Group A had an RCA blockage near the right ventricular branch. Group B, which included 24 people, had an RCA blockage distal to the right ventricular branch. Diabetes mellitus, dyslipidemia, hypertension, smoking, primary PCI, troponin, systolic blood pressure, and heart rate, on the other hand, showed no significant differences between the two groups (70.8 percent in group A vs. 75 percent in group B, $p=0.394$); diabetes mellitus, dyslipidemia, hypertension, smoking, primary PCI, troponin, systolic blood pressure, and heart rate, on the other hand, showed no. The clinical, demographic, and laboratory findings of the patients are summarized in Table 1.

Between the groups, there were no statistically significant variations in EDD, ESD, LAD, or EF. When the measurements of left ventricular diastole were examined, there was no significant difference between the groups. When we looked at the right ventricular function measurements, however, we found significant differences. TAPSE, St, FAC, PAMVUT, and CSV scores were lower in Group A than in Group B (Table 2).

Table 1. Clinical characteristics, demographic and laboratory finding of the study population.

Variables	Group A (n:24, 50%)	Group B (n:24, 50%)	*p* value
Sex male (n, %)	17 (70,8%)	18 (75,0%)	*0,394*
Age (mean±SD)	57.8±10,4	58.3±11,2	*0,543*
HT (n, %)	9 (37,5%)	9 (37,5%)	*0,538*
DM (n, %)	14 (58,3%)	13 (54,1%)	*0,324*
Smoking (n, %)	9 (37,5%)	7 (29,1%)	*0,208*
Dyslipidemia (n, %)	10 (41,6%)	10 (41,6%)	*0,561*
BMI (kg/m2)	25.6±4,4	26.3±4,3	*0,43*
Glucose (mg/dl)	140 (100-182)	148 (100-195)	*0,903*
Creatinine (mg/dl)	0.82±0.24	0.84±0.23	*0,609*
Hemoglobin (mg/dl)	13.6±1,9	13.8±1,8	*0,856*
Troponin (ng/ml)	2.9 (0,3-9,8)	2.3 (0,5-7,2)	*0,513*
Systolic blood pressure (mmHg)	137.9±24,9	135.4±25,1	*0,636*
Heart rate (bpm)	83.1±13,7	79.2±15,1	*0,196*
Door to reperfusion (min)	30 (30-30)	30 (30-30)	*0,457*

BMI, body mass index; DM, diabetes mellitus; HTN, hypertension.

Table 2. Echocardiographic characteristic of the study population.

Variables	Group A (n=24)	Group B (n=24)	*p* value
EDD (cm)	4.7 (4.6-5.1)	4.8 (4.6-5.2)	*0,621*
ESD (cm)	3.1 (2.7-3.3)	3.1 (2.8-3.3)	*0,252*
LAD (cm)	3.4±0.2	3.5±0,2	*0,823*
EF (%)	56 (50-58)	56 (51-58)	*0,965*
LV E/A	0.8 (0.6-0.9)	0.7 (0.6-0.8)	*0.861*
LV E/Em	9 (7-10)	9 (7-10)	*0,59*
TAPSE (cm)	1.6±0.4	1.9±0.5	***<0,001***
St (cm/s)	9 (8-13)	13 (9-15)	***<0,001***
RV MPI	0.5 (0.4-0.6)	0.5 (0.4-0.7)	*0,229*
FAC (%)	31 (26-42)	43 (38-47)	***<0,001***
PAMVUT (cm/s)	9 (7-11)	13 (8-14)	***<0,001***
CSV (cm/s)	17 (15-24)	23 (17-29)	***<0,001***

CSV, combined S velocity; EDD, end diastolic diamater; ESD, end systolic diamater; LAD left atrium diameter, EF, ejection fraction; LV, left ventricle; E, early ventricular filling velocity; A, late ventricular filling velocity; Em ventricular tissue doppler early diastolic velocity, RV right ventricle, TAPSE tricuspid annular plane systolic excursion; PAMVUT, pulmponary annular motion velocity using tissue Doppler imaging; St, tissue Doppler imaging derived tricuspid annulus systolic velocity; MPI myocardial performance index, FAC fractional area change.

CSV was shown to have a positive connection with PAMVUT (r =0.334, *p* =0.001), RV TAPSE (r =0.441, *p* =0.001), FAC (r=0.309, p =0.001), and St (r=0.259, *p* =0.001) in a univariate correlation research (Table 3).

After exhibiting statistical significance in univariate research, TAPSE, St, FAC, PAMVUT, and CSV were evaluated using multivariate logistic regression analysis. The PAMVUT (OR: 0.526, 95 percent CI: 0.309–0.746, p0.001) and CSV (OR: 0.684, 95 percent CI: 0.245–0.713, p0.001) were found as independent predictive predictors for proximal RCA blockage in a multivariate logistic regression test (Table 4).

Table 3. Correlation of RV free wall strain with echocardiographic measurements.

CSV		
Variables	r	*p*
TAPSE (cm)	0,441	*0,001*
FAC (%)	0,309	***<0,001***
St (cm/s)	0,259	*0,001*
PAMVUT (cm/s)	0,334	***<0,001***

CSV: combined S velocity; FAC: fractional area change; PAMVUT: pulmonary annular motion velocity using tissue Doppler imaging; St: tissue Doppler imaging derived tricuspid annulus systolic velocity; TAPSE: tricuspid annular plane systolic excursion.

Table 4. The result of multivariate logistic regression analysis for the prediction of proximal RCA lesion.

Variable	**OR**	**CI**	***p***
PAMVUT (cm/s)	0,526	0,309-0,746	***<0,001***
CSV (cm/s)	0,684	0,245-0,713	***<0,001***

CSV: combined S velocity; PAMVUT: pulmonary annular motion velocity using tissue Doppler imaging; RCA: right coronary artery.

CSV18,3 cm/s and PAMVUT8,6 cm/s had 83 percent sensitivity and 71 percent specificity (AUC=0.83, p0.001), and 85 percent sensitivity and 71 percent specificity (AUC=0,81, *p*<0.001), respectively, in the ROC analysis (Figure 2).

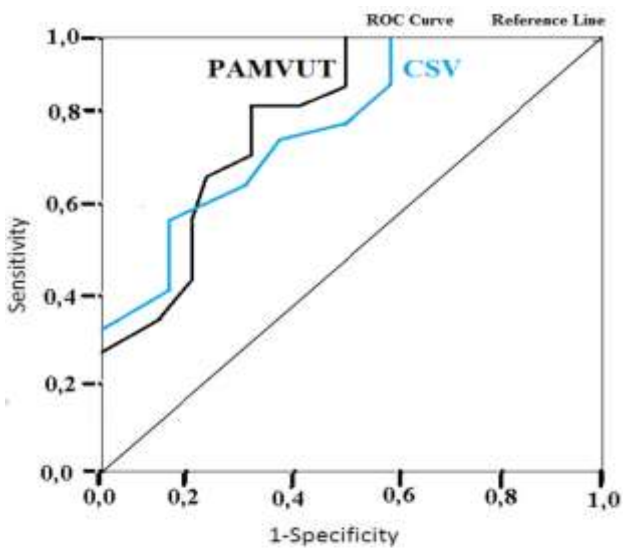

Figure 2. Receiver operating characteristic curve for the prediction of the proximal RCA stenosis RCA, right coronary artery.

Discussion

The PAMVUT and CSV values might predict the proximal RCA lesion in individuals with inferior MI in the current study. In many disorders, determining RV functions is critical for diagnosis, therapy planning, and prognosis evaluation. However, in proportion to their importance, measuring these functions is challenging. The architecture of the RV, which is a complicated three-dimensional (3D) anatomy and morphology, is the most significant difficulty aspect. This scenario may be further explained by citing other examples of limitations [11]. The EF of the entire RV could not be expressed using FAC. The longitudinal mobility of the lateral RV wall is measured by TAPSE and St. The RV endocardial margins are selected using the sine qua non criterion for 3D echocardiographic evaluations [20-22]. Previous research, despite their limitations, sought to get an understanding of global RV functions, particularly by examining parameters such as TAPSE, St, and FAC. Furthermore, ventricular performance in various RV locations may not be equal or comparable, and may have different characteristics depending on the place and illness character.

There are echocardiographic indicators that can indicate proximal RCA lesions in inferior MI, according to the literature. TAPSE was shown to be lower in people with RVMI compared to people without RVMI in a study by Bayata et al. [8]. TAPSE does have limitations, such as reflecting RV free wall longitudinal systole activity, being impacted by LV functions, and producing erroneous high elevation in cases of moderate-to-severe tricuspid regurgitation[23]. In a study of 60 patients with inferior M [I7], Ozdemir et al. discovered that the peak St12 cm/s had a sensitivity of 81 percent and a specificity of 82 percent in diagnosing RVMI and 63 and 88 percent in recognizing the proximal RCA as the infarct-related artery. According to another study, St<8 cm/s has a sensitivity of 78% and a specificity of 86% for diagnosing RVMI in people with inferior MI (n = 50) [24]. The RV-free wall's longitudinal purpose is likewise seen in St. Gecmen et al. [25] found that reduced right ventricular free wall strain was a predictor of proximal RCA blockage in patients with acute inferior MI. It's possible that strain imaging software isn't accessible on every echocardiography instrument. This might result in significant limits in usage.

Furthermore, there is no specialist software for right ventricular strain imaging at the moment; the left ventricle strain imaging program is used on the right ventricle. FAC also has drawbacks, such as its inability to precisely define endocardial boundaries in its calculations, the fact that it ignores RVOT functions, and limited inter-observer reproducibility [26]. PAMVUT is a new parameter for the RVOT function, which is a critical component of RV functions. Hayabuchi et al. found pulmonary annular velocity to be an optimistic echocardiographic metric for characterizing RVOT function in individuals with surgically repaired CHD [13]. Another research found that pulmonary annular velocity correlates RVOT's systolic activity, indicating overall RV function, pulmonary hypertension, right ventricular pressure, volume overload, and illnesses such as surgical injury to the RV myocardium [15]. RVOT functions are reduced in patients with acute inferior MI caused by proximal RCA lesions, according to the literature, and RVOT-SE values can predict proximal RCA lesions [12]. However, in certain individuals, RVOT anterior wall vision with M-mode might be inadequate, making RVOT-SE studies difficult. As a result, the PAMVUT may be able to overcome these restrictions. Another problem of M-mode and TDI-based measurements of the tricuspid annulus and the RV free wall to which it is connected is that they might be inaccurately high, especially in situations of tricuspid regurgitation. For such circumstances, the PAMVUT provides extra parameters. By combining PAMVUT and St, CSV was able to tackle the RV's anatomy-function complexity. For a more precise definition, further research will be required.

The current study contains a number of limitations. To begin with, the trial had a single-center, non-randomized design. Second, there were only a few patients. Finally, because our institution lacked cardiac magnetic resonance (CMR) imaging, we were unable to do CMR, the gold standard for ventricular function. Finally, we lacked predictive information due to the lack of a clinical follow-up.

Conclusion

In patients with acute inferior MI, CSV was utilized to test if it might predict proximal RCA occlusions. CSV values and the PAMVUT were both revealed to be significant predictors of proximal RCA occlusions.

Funding: *The author(s) received no financial support for the research, authorship, and/or publication of this article.*

Conflict of Interest: *The authors declare that they have no conflict of interest.*

Ethical statement**:** *Bolu Abant İzzet Baysal University ethics committee approved the study protocol (Approval ID: 2021/214).*

References

[1]Correale E, Battista R, Martone A, et al. Electrocardiographic patterns in acute inferior myocardial infarction with and without right ventricle involvement: classification, diagnostic and prognostic value, masking effect. Clin Cardiol. 1999;22(1):37-44.

[2]Dima C, Coven Dl, Pershad A et al. Right ventricular infarction. E Medicine. Medscape. https://emedicine.medscape.com/article/157961-overview

[3]Taniguchi T, Shiomi H, Toyota T, et al. Effect of preinfarction angina pectoris on long-term survival in patients with ST-segment elevation myocardial infarction who underwent primary percutaneous coronary intervention. Am J Cardiol. 2014;114(8):1179-86.

[4]Kanovsky J, Kala P, Novotny T, et al. Association of the right ventricle impairment with electrocardiographic localization and related artery in patients with ST-elevation myocardial infarction. J Electrocardiol. 2016;49(6):907-910.

[5]Acar E, Ozgul N, Izci S. The simple right ventricle contraction pressure index: A novel method for echocardiographic assessment of right ventricle dysfunction in acute pulmonary embolism. J Clin Ultrasound. 2021;49(5):466-471.

[6]El Sebaie MH, El Khateeb O. Right ventricular echocardiographic parameters for prediction of proximal right coronary artery lesion in patients with inferior wall myocardial infarction. J Saudi Heart Assoc. 2016;28(2):73-80.

[7]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 J. 2013;65(5):522-28.

[8]Bayata S, Avcı E, Yeşil M, et al. Tricuspid annular motion in right coronary artery-related acute inferior myocardial infarction with or without right ventricular involvement. Anadolu Kardiyol Derg. 2011;11(6):504-8.

[9]Hsiao SH, Chiou KR, Huang WC, et al. Right ventricular infarction and tissue Doppler imaging – insights from acute inferior myocardial infarction after primary coronary intervention–. Circ J. 2010;74(10):2173-80.

[10] Zaborska B, Makowska E, Pilichowska E, et al. The diagnostic and prognostic value of right ventricular myocardial velocities in inferior myocardial infarction treated with primary percutaneous intervention. Kardiol Pol. 2011;69(10):1054-61.

[11] 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.

[12] Nouh S, Said I, Badr A. "Assessment of right ventricular function using right ventricular outflow tract-systolic excursion in inferior wall myocardial infarction and angiographic

correlation to proximal right coronary artery stenosis." Al-Azhar Assiut Medical Journal. 2020;18: 290 – 94.

[13] Hayabuchi Y, Ono A, Homma Y, et al. Pulmonary annular motion velocity reflects right ventricular outflow tract function in children with surgically repaired congenital heart disease. Heart Vessels. 2018;33(3):316-26.

[14] Hayabuchi Y, Ono A, Homma Y, et al. Noninvasive assessment of pulmonary arterial capacitance by pulmonary annular motion velocity in children with ventricular septal defect. Cardiovasc Ultrasound. 2016;14(1):38.

[15] Hayabuchi Y, Ono A, Kagami S. Pulmonary Annular Motion Velocity Assessed Using Doppler Tissue Imaging - Novel Echocardiographic Evaluation of Right Ventricular Outflow Tract Function. Circ J. 2016;80(1):168-76.

[16] Task Force on the management of ST-segment elevation acute myocardial infarction of the European Society of Cardiology (ESC), Steg PG, James SK, Atar D, et al. ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. Eur Heart J. 2012;33(20):2569-619.

[17] Lang RM, Bierig M, Devereux RB, et al. Chamber Quantification Writing Group; American Society of Echocardiography's Guidelines and Standards Committee; European Association of Echocardiography. Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr. 2005;18(12):1440-63.

[18] Lang RM, Badano LP, Mor-Avi V, et al Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr. 2016; 17(4):412.

[19] Popescu BA, Beladan CC, Popescu AC. Diastolic Function Assessment Revisited: Is Big Data Analysis Going to be a Big Hit? JACC Cardiovasc Imaging. 2019;12(7 Pt 1):1162-64.

[20] Dandel M, Hetzer R. Evaluation of the right ventricle by echocardiography: particularities and major challenges. Expert Rev Cardiovasc Ther. 2018;16(4):259-75.

[21] Seo Y, Ishizu T, Atsumi A, et al. Three-dimensional speckle tracking echocardiography. Circ J. 2014;78(6):1290-301.

[22] Vecera J, Bartunek J, Vanderheyden M, et al. Three-dimensional echocardiography-derived vena contracta area at rest and its increase during exercise predicts clinical outcome in mild-moderate functional mitral regurgitation. Circ J. 2014; 78(11): 2741–49.

[23] Choi EY. Accurate and reproducible measurements of right ventricular function in daily practice. J Cardiovasc Ultrasound. 2014 ;22(3):111-12.

[24] Albulushi A, Giannopoulos A, Kafkas N, et al. Acute right ventricular myocardial infarction. Expert Rev Cardiovasc Ther. 2018;16(7):455-64.

[25] Gecmen C, Candan O, Kahyaoglu M, et al. Echocardiographic assessment of right ventricle free wall strain for prediction of right coronary artery proximal lesion in patients with inferior myocardial infarction.

Int J Cardiovasc Imaging. 2018 ;34(7):1109-1116.

[26] Surkova E, and Kovács A. Comprehensive Echocardiographic Assessment of the Right Ventricular Performance: beyond TAPSE and Fractional Area Change. Russ J Cardiol. 2020;25(3S):4067.