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Echocardiographic Assessment of Right Ventricular Out Flow Tract Function in Patients with Chronic Heart Failure

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Abstract

Background: Heart failure is a progressive, clinical disease where a subset of patients has symptoms not related to the hemodynamic status and left ventricular ejection fraction. The Right ventricular function is considered as a prognostic element in HF, although assessing it is challenging because of its complex geometry.

Objective: This study aimed to investigate the clinical application and value of RVOT function measured by transthoracic echocardiography in HF patients.

Method: The investigation of 80 chronic HF patients with dilated dimensions and left ventricular systolic dysfunction (EF less than 40%) ,and 20 healthy control subjects (normal ventricular function ,and normal electrocardiogram) was done. Along with clinical and conventional echocardiographic parameters, RVOT dimensions and fractional shortening (RVOT-FS) were analyzed.

Results: The RVOT-FS was less in HF patients than healthy controls (34.4 ± 10.1 vs 57.5 ± 2.5, $p < 0.001$) and correlated positively with TAPSE ($p < 0.001$) and inversely with SPAP ($p < 0.001$) . There was a statistically significant difference in RVOT-FS among the HF subgroups with regard to NYHA functional capacity ($p < 0.001$), although there was no statistically significant difference with regard to LVEF.

Conclusion: The discordance between LVEF and the degree of functional impairment in HF is not well understood, it could be explained partly by alteration in RV function. It was found that the RVOT function was a noninvasive and easily applicable measure of RV function. This study showed that RVOT function is related to the functional capacity in heart failure patients.

Keywords: RVOT ; Heart Failure ; NYHA classification

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INTRODUCTION

Heart failure (HF) is a common, progressive, complex syndrome with high morbidity and mortality. Decreased exercise capacity is the main symptom in heart failure patients; therefore, the physician should provide an estimation of the functional class of the patient based on an assessment of the patients' daily activity and the limitations imposed by the patient's symptoms of HF. The New-York Heart Association classification (NYHA) has been long used to categorize patients with heart failure and this classification provides important prognostic information.[1,2,3]

Although HF is generally regarded as hemodynamic disorder, many studies have indicated that there is a poor relationship between measures of cardiac performance and the symptoms produced by the disease. However, a subset of patients with HF has symptoms out of proportion to the resting hemodynamics. Patients with very low left ventricular ejection fraction (LVEF) may be asymptomatic, whereas patients with preserved LVEF may have severe disability. The apparent discordance between LVEF and the degree of functional impairment is not well understood but may be explained by alterations in ventricular distensibility, valvular regurgitation, pericardial restraint, cardiac rhythm abnormalities, and left atrial or right ventricular (RV) function.[4,5]

Recently, RV function has been found to be a powerful prognostic factor in heart failure and pulmonary hypertension, but assessing it is a challenge because of right ventricle's complex geometry, its relationship with the left ventricle (LV), its extreme sensitivity to loading conditions and to alteration in pulmonary pressure, and limited understanding of underlying mechanisms of right heart failure. Some studies have shown that in patients with advanced heart failure, RV function determines exercise capacity and survival.[6]

Due to its wide spread, echocardiography is used as the first line modality of assessing RV function and size. Although several echocardiographic parameters have been proposed, accurate global assessment of the RV is still challenging because of its complex anatomy; RV is not one chamber, but is composed of two distinct anatomic units, the RV sinus (from the tricuspid valve annulus to the proximal os infundibulum) and right ventricular outflow tract (RVOT) (from proximal os infundibulum to the pulmonary valve).[7,8] The RV shortens in circumferential direction during isovolumetric contraction controlled by subepicardial fibers and longitudinally during the ejection phase controlled by subendocardial fibers. The RVOT function has been found to correlate closely with other anatomical, long axis as well as functional parameters and trans-tricuspid retrograde pressure gradient.[9, 10]

Although the inlet part of the RV has a greater contribution to overall RV functions compared with the infundibulum, some studies have reported the possibility of using RVOT movement or contraction as a marker of RV systolic function. [8, 10,11]

Regional RVOT dysfunction is suggested to affect exercise tolerance after tetralogy of Fallot repair. Therefore, RVOT appears to have its own hemodynamic characteristics by reflecting the RV sinus and pulmonary artery.[12,13]

Therefore this study will be aimed to evaluate the clinical and functional significance of RVOT in patients with chronic heart failure.

PATIENTS AND METHODS

A total of 100 patients referred to Al-Galaa military hospital echocardiography unit in the period from June 2018 to September 2019, divided as (HF group) consisted of 80 Patients with chronic HF patients (EF less than 40%) with dilated heart and LV systolic dysfunction, and (control group) with 20 healthy control subjects (normal ventricular function and ECG, no history of cardiac diseases). The study patients had a clinical diagnosis of HF made based on compatible clinical presentation and history combined with documented systolic LV dysfunction (LVEF <40%) and dilation by transthoracic echocardiography. All patients were on standard HF therapy according to the recent guidelines (ESC recommendations of cardiac chamber quantification 2016) and all patients had history of coronary angiography. Patients were divided into 3 subgroups according to their NYHA functional class:

Subgroup 1 (NYHA class I, no symptoms with ordinary activity; NYHA class II, mild limitation of physical activity and symptoms with ordinary physical activity)

Subgroup 2 (NYHA class III, marked limitation of physical activity and symptoms with less than ordinary physical activity)

Subgroup 3 (NYHA class IV, symptoms with any physical activity or at rest). A sub-study where the study patients were divided according to type of cardiomyopathy (ischemic cardiomyopathy and dilated cardiomyopathy).the ischemic cardiomyopathy group were classified into ischemic cardiomyopathy with evidence of RV infarction, and ischemic cardiomyopathy without RV infarction.

Inclusion criteria: Adult patients with chronic left sided heart failure (heart failure more than 12 months with EF< 40%).

Exclusion criteria: All patients with Congenital heart defects. Valvular heart disease. Infectious disorders. Malignant tumors. Patients with Group1 pulmonary hypertension (e.g. pulmonary arterial hypertension), Group3 pulmonary hypertension (pulmonary hypertension associated with lung disease and/or hypoxia), Group 4 pulmonary hypertension (pulmonary hypertension due to chronic thrombotic or embolic disease) and Group 5 pulmonary hypertension (pulmonary hypertension due to miscellaneous causes).

All Patients were subjected to the following: Informed written consent. Detailed full history with special emphasis on: a- Age and gender. b- Hypertension. c- Diabetes mellitus. d- Ischemic or valvular heart disease. Clinical (general and local) examination. Resting 12 leads ECG. Transthoracic 2D echocardiography using GE vivid 7 with 3.0 MHz phased array transducer to assess: Left ventricular end diastolic and end diastolic dimensions (LVIDd and LVIDs). Left ventricular systolic function by M-mode method in parasternal long axis view, also by biplane simpson method in apical views. Assesment of LV diastolic function by transmitral pulsed wave doppler to measure velocity of E wave, and by tissue doppler at lateral mitral valve annulus to measure velocity of E' wave, then value of E/E'. SPAP to be estimated by continuous wave doppler evaluation of tricuspid regurge. Tricuspid annular systolic excursion (TAPSE) from apical four chamber view with M-mode cursor placed at free wall angle of tricuspid valve, the distance between tricuspid annulus and the RV apex is measured at end diastole and end systole and TAPSE is calculated in millimeters as the difference between end diastolic and end systolic measurements. RVOT dimensions and fractional shortening obtained from parasternal short axis view at level of aortic root. M-mode recordings of the RVOT will be obtained and dimensions to be measured at end diastole and end systole. RVOT fractional area change to be calculated as the percentage fall in RVOT diameter in systole with respect to that in diastole using the M-mode images. RA, RV base and mid dimensions in apical 4 chamber view by measuring linear and longitudinal dimensions.

Data were analyzed using Statistical Program for Social Science (SPSS) version 25.0 for windows. Quantitative data were expressed as mean ± standard deviation (SD). Qualitative data were expressed as frequency and percentage.

The following tests were done: Independent-samples t-test of significance was used when comparing between two means of normally distributed data. A one-way analysis of variance (ANOVA) was used when comparing between more than two means if data is normally distributed. Chi-square (X2) test also called Pearson's chi-square test or the chi-square test of association, is used to discover if there is a relationship between two categorical variables. Fisher Exact test is a test of significance that is used in the place of chi square test in 2 by 2 tables, especially in cases of small samples. The "Linear-by-Linear" test is for ordinal (ordered) categories and assumes equal and ordered intervals. The Linear-by-Linear Association test is a test for trends in a larger than 2x2 table. Pearson's coefficients were calculated to assess relationship between study parameters, (+) sign indicate direct correlation & (-) sign indicate inverse correlation, also values near to 1 indicate strong correlation & values near zero indicate weak correlation. Probability (p-value): p-value <0.05 was considered significant, p-value <0.001 was considered as highly significant and p-value >0.05 was considered insignificant.

RESULTS

Echocardiographic data	HF group	Control group	P-value (Sig.)
Count	80	20	
Ao (cm)	3.0 ± 0.3	2.5 ± 0.2	<0.001
LA (cm)	4.6 ± 0.5	3.2 ± 0.3	<0.001
LVIDd (cm)	6.3 ± 0.5	4.4 ± 0.3	<0.001
LVIDs (cm)	5.5 ± 0.5	3.0 ± 0.3	<0.001
EF (%)	32.1 ± 4.9	67.5 ± 4.2	<0.001
FS (%)	12.7 ± 2.6	31.2 ± 2.9	<0.001
RVOT-es (cm)	2.18 ± 0.57	1.09 ± 0.14	<0.001
RVOT-ed (cm)	3.20 ± 0.53	2.55 ± 0.22	<0.001
RVOT-FS (%)	34.4 ± 10.1	57.5 ± 2.5	<0.001
MV E vel (m/s)	0.91 ± 0.24	0.75 ± 0.07	0.004
MV E' lateral (m/s)	0.07 ± 0.02	0.12 ± 0.02	<0.001
E/E'	12.9 ± 2.9	6.5 ± 1.3	<0.001
TAPSE (mm)	15.9 ± 4.1	26.2 ± 2.9	<0.001
PAP (mmHg)	42.2 ± 13.3	17.7 ± 3.8	<0.001
RA (cm)	4.3 ± 0.5	2.9 ± 0.2	<0.001
RV base (cm)	4.1 ± 0.5	2.9 ± 0.2	<0.001
RV mid (cm)	3.4 ± 0.5	2.1 ± 0.1	<0.001

Table 1: Comparison between the studied groups regarding the echocardiographic data. P < 0.05 is significant.

Echocardiographic data	NYHA I & II	NYHA III	NYHA IV	P-value (Sig.)
Count	43	20	17	
Ao (cm)	3.0 ± 0.3	2.9 ± 0.3	3.0 ± 0.4	0.582
LA (cm)	4.5 ± 0.4	4.6 ± 0.5	4.9 ± 0.5	0.014
LVIDd (cm)	6.2 ± 0.4	6.2 ± 0.4	6.6 ± 0.6	0.024
LVIDs (cm)	5.4 ± 0.4	5.4 ± 0.4	5.7 ± 0.6	0.100
EF (%)	32.7 ± 4.4	31.6 ± 4.2	31.2 ± 6.5	0.480
FS (%)	12.9 ± 2.4	12.5 ± 1.6	12.3 ± 3.8	0.756
RVOT-es (cm)	1.88 ± 0.55	2.39 ± 0.34	2.68 ± 0.34	<0.001
RVOT-ed (cm)	2.97 ± 0.52	3.45 ± 0.44	3.48 ± 0.41	<0.001
RVOT-FS (%)	41.1 ± 8.4	29.8 ± 3.6	23.1 ± 4.5	<0.001
MV E vel (m/s)	0.80 ± 0.25	1.07 ± 0.20	1.04 ± 0.13	<0.001
MV A vel (m/s)	0.68 ± 0.20	0.60 ± 0.17	0.62 ± 0.21	0.005
MV E' lateral (m/s)	0.07 ± 0.02	0.07 ± 0.02	0.07 ± 0.01	0.356
E/A ratio	1.29 ± 0.60	1.77 ± 0.45	2.29 ± 0.68	<0.001
E/E'	11.4 ± 2.2	13.8 ± 1.9	15.6 ± 3.4	<0.001
TAPSE (mm)	18.8 ± 2.8	13.9 ± 2.7	11.2 ± 2.1	<0.001
PAP (mmHg)	35.8 ± 10.9	46.9 ± 9.4	52.8 ± 14.0	<0.001
RA (cm)	4.0 ± 0.4	4.6 ± 0.2	4.8 ± 0.4	<0.001
RV base (cm)	3.8 ± 0.3	4.4 ± 0.3	4.6 ± 0.5	<0.001
RV mid (cm)	3.1 ± 0.4	3.8 ± 0.4	3.9 ± 0.4	<0.001

Table 2: Comparison between the NYHA subgroups of HF patients (n=80) regarding the echocardiographic data.

DISCUSSION

Assessment of RV function is important to understand the pathophysiology of heart failure; however, it is still challenging to find a simple and comprehensive parameter by echocardiogram. In this study, it has demonstrated that RVOT-FS reflects the severity of both left- and right-sided ventricular function.

Many studies had shown that the relationship between symptoms of heart failure & disability, and degree of left ventricular impairment is not a powerful one. Also it was found that RV functions affects directly the functional capacity in patients with left sided heart failure. The complicated anatomy of the right ventricle makes assessing its functions laborious. RVOT dimensions and functions were found to be of a good use in assessing RV functions and functional capacity of left sided failure .[8, 14, 16]

RV originates from a different embryological source to LV. RVOT is defined as a region between the sub-pulmonary infundibulm and pulmonary valve, and is distinct from the rest of RV in origin and anatomy. [17-18]

Recently, the interest has been increasing in the RV, especially with regard to LV failure. Many studies have shown that exercise capacity, as measured by peak VO_2, is more closely associated with RV functions than with LVEF .[9,19,22]

It has also shown that RV function is an important predictor of both response to CRT and long-term clinical outcome of HF patients, and routine assessment of the RV is recommended in the evaluation of HF patients for CRT .[22-23]

In This study it was found that RVOT-FS is lower in HF patients than in healthy controls, also RVOT-FS was correlated inversely with NYHA functional capacity Although LVEF is close among different HF subgroups in agreement with Yamaguchi et al.[12] that stated that RVOT size and contraction were correlated with functional capacity, although this study was on 36 patients it was supported by Yamaguchi et al.[12] study that was done on 81 patients, as they found that on follow up echocardiogram in patients with LVSD, it was observed that deterioration of RVOT-FS with a minimal change in LVEF resulted in a poor outcome in these patients.

It was found that TAPSE differed among different heart failure subgroups, it was highest in NYHA I&II and lowest in NYHA IV subgroup. RVOT-FS was corelated directly with TAPSE in agreement with Lindqvist et al.[11] that reported that RVOT-FS moderately correlated with TAPSE, also in agreement with as they mentioned that RVOT-FS was significant related to TAPSE and can be used as an easy, reliable method to asses RV function which also Yamaguchi et al.[12] stated. Similar to RVOT-FS, Asmer et al.[8] reported that RVOT systolic excursion, which is actually a component of RVOT-FS, is novel, simple, and promising parameter for assessing RV function. As a part of right side assessment, we corelated the RVOT-FS with PAP measured by trans-tricuspid doppler method and showed a variation among HF subgroups with increasing PAP in NYHA class IV than the other two groups alike to what was stated by Lindqvist et al.[11] Also in agreement with Lindqvist et al.[11] it was found that RVOT-FS was inversely related to PAP.

This study measured LV diastolic function by trans-mitral pulsed wave to get the values of E wave velocity values and by tissue doppler techniques to get E' velocity value at mitral valve annulus, then E/E' ratio was calculated and the results showed that there was a significant difference among HF subgroups where NYHA I&II subgroup had better diastolic functions than NYHA class III subgroup and NYHA class IV subgroup that showed the most impaired diastolic function. Correlated to RVOT-FS, diastolic function was inversely related to RVOT-FS, which give an idea that RVOT may have a role in LV diastolic disfunction, which need further studies to understand the relation between them.

On analyzing patients according to the history of RV infarction, the RVOT-FS and functional capacity were lower in patients with history of RV infarction than in patients without RV infarction in patients with ischemic cardiomyopathy which needs further studies to improvise the relationship between RVOT function and the presence of history of RV infarction.

CONCLUSION

The discordance between LVEF and the degree of functional impairment in HF is not well understood in some patients, it may be explained in part by alterations in RV and RVOT function.

This study demonstrated that the RVOT-FS was a noninvasive and easily applicable measure of RV function and might be used as a parameter to assess the severity of both ventricular functions, evaluation, prognosis, and follow-up of HF patients, as it is correlated to functional capacity in the left sided heart failure patients (inversely proportionate relationship with NYHA classification) .

Besides, RVOT-FS gives a good estimation of right ventricular function as it is correlated well with other right ventricular function parameters.

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