https://doi.org/10.48047/AFJBS.6.14.2024.5492-5501

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

Assessment of Right Ventricular Mechanics by Two Dimensional Speckle Tracking Echocardiography in Hypertensive Patients

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Article History
Received: 28 April 2024,
Accepted: 28 June 2024,
Published: 18 August 2024
doi:10.48047/AFJBS.6.14.2024.5492-5501

Abstract

Arterial hypertension is an established major and highly prevalent cardiovascular risk factor. The study aimed to use Speckle Tracking to evaluate right ventricular function in patients with systemic arterial hypertension. Acase control hospital based study which was conducted at Faculty of Medicine, Menoufia Governorate at the duration of two years started at 2020 till 2022. 150 subjects were included in this study divided into 2 groups. There was statistically significant negative correlation between interventricular septal thickness at end diastole and Tricuspid annular plane systolic excursion (TAPSE), Fractional area change (FAC %), Systolic TV annular velocity (S') of the RV using Tissue Doppler imaging and Global right ventricular strain using two- dimensional echocardiography (%). TAPSE (mm), FAC (%), S'(cm/s) and 2D-RVGLS (%) are depressed with increasing IVSd in hypertensive group. Conclusion: RV strain parameters measured by 2D- speckle tracking echocardiography have the highest accuracy in detection of RV impairment.

Keywords: Right ventricular mechanics, Two dimensional speckle tracking , Echocardiography, Hypertension.

Introduction

Left ventricular hypertrophy is often associated with hypertension and is an adaptive mechanism to maintain or normalize wall stress, sometimes at the expense of diastolic and long-axis systolic function **(1,2)**. This adaptive mechanism is associated with changes in left ventricular parameters and in chamber dimensions, geometry and function **(2,3)**. These changes are progressive and can ultimately lead to heart failure with systolic and/or diastolic dysfunction. However, the human heart functions as a unit that includes the right ventricle **(4,5)**.

The spectrum of changes in structure, function and shape of the left ventricle ultimately has an effect on the structure and function of the right ventricle. The right ventricle is a thin- walled, low-pressure system. Studies that evaluated left ventricular function abound in the literature. However, studies about right ventricular structure and function among hypertensive subjects are rare **(6,7)**. Possible morphological and/or functional changes might occur in the right ventricle in subjects with systemic hypertension **(8,9)**.

Echocardiography is a very useful and non-invasive diagnostic tool, which can be used to diagnose ventricular hypertrophy and various flow and pressure parameters in all cardiac chambers **(10,11)**. Echocardiography in the evaluation of right ventricular function is important, as right ventricular dysfunction has been shown to correlate significantly with disease progression in subjects with chronic obstructive pulmonary disease, dilated cardiomyopathy and secondary pulmonary hypertension **(12,13)**.

Therefore, we proposed that it is important to document any possible right ventricular systolic and/or diastolic dysfunction in subjects with systemic hypertension.

Patients and Methods

The study was conducted at Menoufia University Hospitals. All patients were recruited from the cardiology department. The study was carried out during the period from September 2020 to October 2022. 150 subjects were included in this study divided into 2 groups:

- Group A (Cases):100 patients with systemic arterial hypertension.
- Group B (Control): 50 healthy age and sex matched volunteers free from cardiovascular risk factors.

Consecutive sampling technique till reaching a sample size of 100 patients was adopted, another 50 persons were collected as control group.

Inclusion Criteria

Patients known to be hypertensive. Patients with office SBP values >_140 mmHg and/or diastolic BP (DBP) values >_90 mmHg. Patients on antihypertensive treatment.

Exclusion Criteria

Patients with chronic obstructive pulmonary disease, diabetes mellitus, history of coronary artery disease, previous myocardial infarction, left ventricle systolic dysfunction less than 50% , hypertrophic Cardiomyopathy and arrhythmogenic right ventricular cardiomyopathy, congenital heart diseases as pulmonary stenosis, fallot's tetralog and Ebstein anomaly, cardiac arrhythmias as atrial fibrillation.

Clinical assessment

Patients were subjected to full history taking & complete clinical examination including pulse, heart rate, blood pressure (SBP & DBP), height, weight, body mass index, neck veins and lower limbs. Cardiac examination including auscultation of the heart to detect abnormal sounds and murmurs. Resting 12-lead surface ECG to detect ischemic changes (ST-T wave changes) and any arrhythmias. Plain chest X-rays to evaluate lung condition e.g. chronic obstructive pulmonary diseases, interstitial pulmonary diseases, configuration of pulmonary artery and to assess cardiomegaly.

Transthoracic echocardiography:

All subjects were examined in left lateral decubitus position, to bring the heart forward to the chest wall and lateral to the sternum, as recommended by the American Society of Echocardiography (ASE) and the European Association of Cardiovascular Imaging (EACVI).

Two dimensional and M-mode echocardiographic examinations to measure:

1. LV end diastolic dimension, LV end systolic dimension, posterior wall thickness at end diastole, septal thickness at end diastole, LV fractional shortening and LV Ejection Fraction (EF) (%).
2. RV function will be measured using:

a) Tricuspid Annular Plane Systolic Excursion (TAPSE): TAPSE was acquired by placing an M-mode cursor through the tricuspid lateral annulus and measuring the amount of longitudinal motion of the annulus at peak systole with the lower reference value for impaired RV systolic function equals 19 mm,

b) FAC was calculated in the apical 4 -chamber view,defined as the difference between end-diastolic and end-systolic area divided by the end- diastolic area and multiplied by 100.the lower reference value is 35% .

c) Tissue Doppler imaging for right ventricular function: Systolic TV annular velocity (S').S' was measured in apical 4-chamber view in which a tissue Doppler mode highlighting the RV free wall was done.

d) Speckle tracking echocardiography (STE) of the Global right ventricular strain.

Statistical Analysis:

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp) Qualitative data were described using number and percent. The Shapiro-Wilk test was used to verify the normality of distribution Quantitative data were described using range (minimum and maximum), mean, standard deviation, median and interquartile range (IQR). Significance of the obtained results was judged at the 5% level.

Results

I. Clinicopathologic characteristics:

100 patients with systemic arterial hypertension were included in this study , referred to Menoufia university hospital for treatment and another 50 healthy, age and sex matched volunteers as a control group. The study population was divided into two groups. Regarding age the mean age for group A (cases) was 55.26 ± 10.20years , and the mean age for group B (control group) was 44.28 ± 11.32 years .There was highly statistical significant difference between the two groups as regard age (p-value <0.001).

Regarding Gender distribution 58.5% of the study population were males and 41.5% were females. Group A (cases group) 55% were males and 45% were females and group B (control group) also 62%were males and 38%were females.Group A (cases group) 55% were males and 45% were females and group B (control group) also 62%were males and 38 %were females. Regarding anthropometric data there was statically significant difference between the two studied groups as regard BMI which was higher in group A. (p-value 0.023*). There was highly statistically significant difference in the systolic and diastolic blood pressure between the studied groups, where 66.6% of the study population were hypertensive and 33.34% were normotensives. Group A (cases) all subjects have systemic arterial hypertension, while group B (control group) all subjects were normotensives (p- value: <0.001) and DBP (p-value: <0.001) **(Table 1)**.

II. Conventional Echocardiography:

Regarding left ventricular measuring parameters in Table (1) showed that there was a highly statistically significant difference between the two studied groups regarding LV posterior wall thickness at end diastole, interventricular septal thickness at end diastole, where they were increased in group A in comparison to group B with p-value <0.001.

Regarding right ventricular measuring parameters table 2 showed that right ventricular function was affected in group A than group B where (a)Tricuspid annular plain systolic excursion (TAPSE) was with highly statistically significant difference between the studied groups, where TAPSE was 17.34 mm in group A versus 23.0 in group B with p-value <0.001. (b)Fractional area change (FAC%) was with highly statistically significant difference between the studied groups, where FAC was 32.08% in group A versus 46.28% in group B with p-value <0.001. (c)Tissue Doppler imaging for right ventricular function: Systolic TV annular velocity (S') was with highly statistically significant difference between the studied groups ,where S' was 9.31 cm/s in group A versus 12.60 cm/s in group B with p-value<0.001.(d) Global right ventricular strain using two-dimensional echocardiography (%):was with highly statistically significant difference between the studied groups ,where 2D-RVGLS was -19.13% in group A versus-25.66 % in group B with p-value <0.001 **(Table 2,Fig .1,2)**.

III. Regarding correlations

Left ventricular hypertrophy is a condition in which there is an increase in left ventricle mass index with increase in interventricular septum and posterior walls thickness ,this condition was associated with right ventricular affection.as in this study there was statistically significant negative correlation between interventricular septal thickness at end diastole , left ventricular posterior wall thickness and Tricuspid annular plane systolic excursion(TAPSE) ,Fractional area change (FAC %), Systolic TV annular velocity (S') of the RV using Tissue Doppler imaging, highly statistically negative correlation with GLS and Global right ventricular strain using two-dimensional echocardiography(%) with p-value<0.001.TAPSE (mm), FAC (%), S'(cm/s) and 2D-RVGLS (%) are depressed with increasing IVSd and LVPWD in hypertensive group **(Table 3)**.

Table (1): Comparison between the two studied groups according to different parameters

parameters	Group A (n = 100)	Group B (n = 50)	t	p
IVSd (mm)				
Min. – Max.	11.0 – 15.0	6.0 – 11.0		
Mean ± SD.	12.56 ± 1.27	8.62 ± 1.26	17.998*	<0.001*
Median (IQR)	12.0(12.0 – 13.0)	9.0(8.0 – 10.0)		
LVPWd (mm)				
Min. – Max.	11.0 – 15.0	6.0 – 12.0		
Mean ± SD.	12.34 ± 1.09	8.92 ± 1.28	17.066*	<0.001*
Median (IQR)	12.0(12.0 – 13.0)	9.0(8.0 – 10.0)		
LVEDd (mm)				
Min. – Max.	39.0 – 57.0	40.0 – 56.0		
Mean ± SD.	49.55 ± 4.48	50.44 ± 3.98	1.190	0.236
Median (IQR)	50.0(46.5 – 53.0)	51.0(49.0 – 53.0)		
LVEDs (mm)				
Min. – Max.	21.0 – 44.0	22.0 – 37.0		
Mean ± SD.	32.01 ± 4.88	31.86 ± 3.91	0.189	0.850
Median (IQR)	32.50(28.0 – 35.5)	32.50(29.0 – 35.0)		
LVEF (%)				
Min. – Max.	50.0 – 79.0	55.0 – 79.0		
Mean ± SD.	62.82 ± 7.59	65.68 ± 6.48	2.283*	0.024*
Median (IQR)	63.0(57.0 – 68.0)	65.0(60.0 – 71.0)		
LVFS (%)				
Min. – Max.	23.0 – 48.0	26.0 – 48.0		
Mean ± SD.	32.52 ± 6.15	34.50 ± 5.04	1.971	0.051
Median (IQR)	32.0(27.0 – 37.0)	34.0(31.0 – 36.0)		

*IQR: Inter quartile range, SD: Standard deviation, t: Student t-test, p: p value for comparing between the studied groups, *: Statistically significant at p ≤ 0.05, Group A: Hypertensive group, Group B: Normotesive group*

Table (2): Comparison between the two studied groups according to different parameters

parameters	Group A (n = 100)	Group B (n = 50)	t	p
TAPSE (mm)				
Min. – Max.	7.0 – 20.0	19.0 – 25.0		
Mean ± SD.	17.34 ± 2.06	22.44 ± 1.77	14.942*	<0.001*
Median (IQR)	18.0(16.0 – 19.0)	23.0(21.0 – 24.0)		
FAC (%)				
Min. – Max.	23.0 – 43.0	35.0 – 52.0		
Mean ± SD.	32.08 ± 3.61	46.28 ± 4.57	19.185*	<0.001*
Median (IQR)	33.0(30.0 – 34.0)	48.0(45.0 – 50.0)		
S' (cm/s)				
Min. – Max.	7.0 – 13.0	11.0 – 15.0	18.266*	<0.001*
Mean ± SD.	9.31 ± 1.20	12.60 ± 0.95		
Median (IQR)	9.50(8.0 – 10.0)	12.50(12.0 – 13.0)		
2D-RVGLS (%)				
Min. – Max.	-23.0 : -15.0	-28.0 – -23.0		
Mean ± SD.	-19.13± 2.12	-25.66 ± 1.47	22.047*	<0.001*
Median (IQR)	-20.0 (-21.0 : -17.0)	-25.50(-27.0 – -24.0)		

IQR: Inter quartile range, SD: Standard deviation, t: Student t-test, *p: p value for comparing between the studied groups, **: highly Statistically significant at p ≤ 0.001, Group A: Hypertensive group Group B: Normotesive group, Group B: Normotesive group*

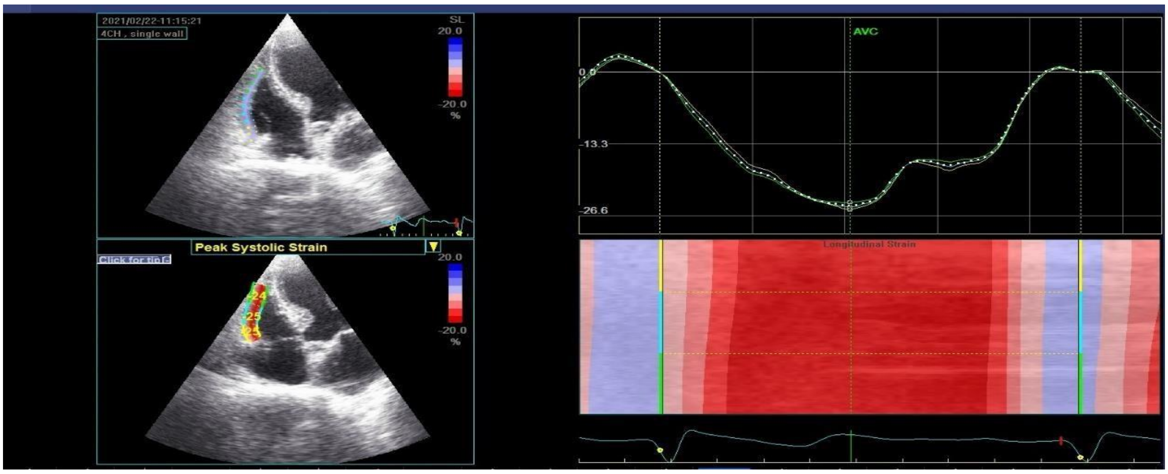

Figure (1): Shows normal right ventricular global longitudinal systolic strain (%) by two dimensional speckle tracking in a healthy subject in apical four chamber view.

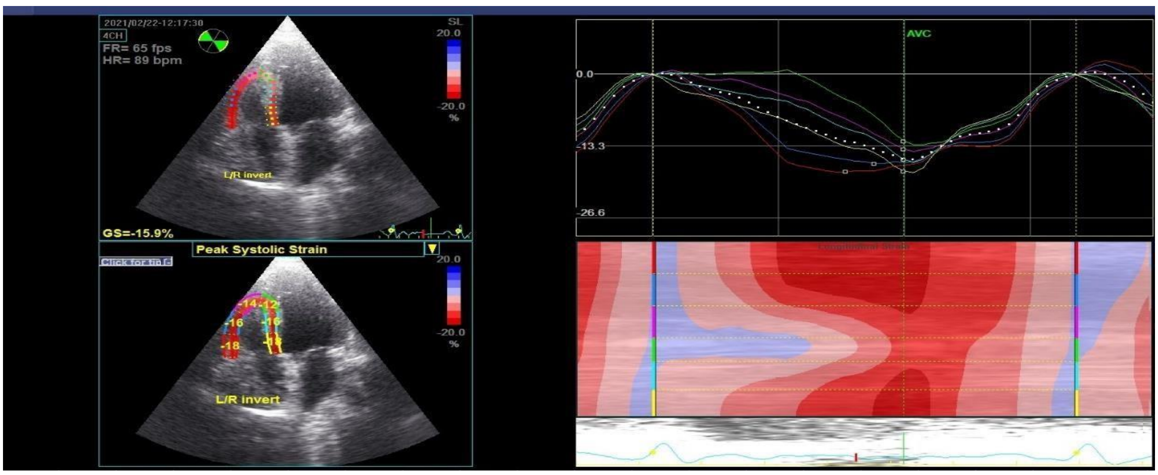

Figure (2): Shows impaired right ventricular global longitudinal systolic strain (%) by two dimensional speckle tracking in a Patient with systemic arterial hypertension in apical four chamber view.

Table (3): Correlation between IVSd (mm) and LVPWd (mm) with different parameters: TAPSE, FAC %, S' of the RV using Tissue Doppler imaging and Global right ventricular strain using two-dimensional echocardiography(%) in cases group (n= 100)

parameters	IVSd (mm)		LVPWd (mm)	
	r	p	r	p
TAPSE (mm)	-0.221	0.027*	-0.303	0.002*
FAC (%)	-0.246	0.014*	-0.278	0.005*
S' (cm/s)	-0.208	0.038*	-0.227	0.023*
2D-RVGLS (%)	-0.665	<0.001*	-0.512	<0.001*

*r: Pearson coefficient, *: Statistically significant at p ≤ 0.05, **: Statistically highly significant at p ≤ 0.001*

Discussion

Our study included 150 subjects, divided into two groups, group A: 100 hypertensive patients and group B: 50 controls .LV hypertrophy and increased mass index of LV was reported in hypertensive group compared to the normo-tensive group.

Regarding the age our study demonstrated that there was highly statistical significant difference between the two groups as regard age (p-value <0.001). This data consistent with the result of a pooled analysis of 1479 population-based measurement studies with 19.1 million participants to assess he worldwide trends in blood pressure from 1975 to 2015 **(14)**.

Also there is numerous studies discussed the prevalence of arterial hypertension worldwide and impact of the aging ,sex distribution and special habits on this prevalence as the study performed by **Twagirumukiza et al.(15)** to estimate Current and projected prevalence of arterial hypertension in sub-Saharan Africa by sex, age and habitat. This study concluded that the estimated number of hypertensives in 2008 is nearly four times higher than the last 2005 estimate of the World Health Organization Regional Office for Africa. Prevalences were significantly higher in urban than in rural populations. Population data are lacking in many countries underlining the need for national surveys **(16)**.

Regarding anthropometric data, our study showed statically significant difference between the two studied groups as regard BMI that was higher in group A. These data consistent with **Landi et al.(16)** who studied the correlation between BMI and hypertension and found that body Mass Index is strongly associated with Hypertension and it is possible to confirm that BMI was an independent risk factor for hypertension. Therefore, BMI measurement should be recommended as a simple and effective predictor of hypertension in public health strategies.

As regarding vital sings, our study showed that there was highly statistically significant difference between the studied groups, where mean heart rate was 80.4 bpm in group A versus 71.48 bpm in group B with p-value <0.001. As the mean blood pressure was 138.1 mmhg for SBP & 85.15 mmhg for DBP in group A versus 123.1 mmhg for SBP & 76.7 mmhg for DBP in group B with p-value <0.001. This fact proved by **Palatini et al. (17)** as they analyzed relationship of tachycardia With High Blood Pressure and Metabolic Abnormalities.

The aim of this study was to investigate the distribution of heart rate and its relationship with blood pressure and other cardiovascular risk factors. This study demonstrated that resting clinic heart rate is an independent risk factor for adult cardiovascular disease in general and coronary heart disease in particular **(17)**.

Our study showed that there was a highly statistically significant difference between the two studied groups regarding LV posterior wall thickness at end diastole, interventricular septal thickness at end diastole, where they were increased in group A in comparison to group B with p-value <0.001.

This fact is consistent with the result of **Cuspidi et al. (18)** in their review paper, so they made analysis for 30 studies and demonstrated one of the largest databases on echocardiographic LVH prevalence in the hypertensive population of 37 700 patients from different studies. The main finding of their work was that 36 - 41% of both treated and untreated hypertensive patients had alterations in cardiac structure. Influence of arterial hypertension on LV ventricle is well established. However, the effect on right ventricular (RV) remodeling is still being investigated **(18,19)**.

The aim of our study was to discover any early changes in RV systolic functions caused by systemic BP elevation with consequent LV hypertrophy (LVH) that might subsequently help in early diagnosis and hence it is early treatment. In our study to evaluate RV systolic function, we used different techniques and parameters.

A. Tricuspid annular plain systolic excursion (TAPSE),

A good estimate of RV global systolic function, was also reduced also in our hypertensive group compared with normo-tensive individuals, with highly statistically significant difference between the studied groups, where TAPSE was 17.34 mm in group A versus 23.0 in group B with p-value <0.001. These results were consistent with the results of the study of Pedrinelli et al., tissue Doppler systolic velocity recorded at tricuspid annulus was reduced in mildly hypertensive patients and in high normal blood pressure group when compared to normo-tensive group **(20)**.

B. Fractional area change (FAC)

This is a parameter of RV systolic function, was measured in the two groups. FAC was deteriorated in our hypertensive patients compared with normotensive individuals with highly statistically significant difference between the studied groups ,where FAC was 32.08% in group A versus 46.28% in group B with p-value <0.001. These results consistent with **Pedrinelli et al. (21)** who found that Tricuspid e′/a′ ratio was reduced and relaxation time was prolonged in hypertensive patients. RV relaxation time positively correlated with RV wall thickness while tricuspid E/A ratio correlated with mitral E/A ratio.

C. Tissue Doppler imaging for right ventricular function:

Systolic TV annular velocity (S’): Was with highly statistically significant difference between the studied groups, where S’ was 9.31 cm/s in group A versus 12.60 cm/s in group B with p-value<0.001. These results were concordant with the study performed by **Pedrinelli et al. (21)** who revealed that Tricuspid early diastolic flow velocity and systolic velocity assessed by tissue Doppler gradually decreased with elevation of blood pressure. Both parameters correlated negatively with septal thickness.

D. Global right ventricular strain using two-dimensional echocardiography (%):

In our study we investigated RV mechanics in hypertensive patients using Two-dimensional speckle tracking echocardiography (Global longitudinal strain) that revealed significant deterioration of RV longitudinal deformation and revealed the association between RV longitudinal strain and functional capacity in hypertensive patients with highly statistically significant difference between the studied groups, where 2D-RVGLS was -19.13% in group A versus -25.66 % in group B with p-value <0.001

Our study consistent with the study performed by **Xue et al. (22)** where the systolic function of the right ventricular myocardium declined in the elderly with essential hypertension due to impaired myocardial mechanics. The right ventricular strain parameters could indicate mechanical damage in the concentric remodeling group earlier than the right ventricular three-dimensional volume and function parameters. The right ventricular free wall longitudinal strain was primarily subject to the LVMI.

In our study, there was statistically significant negative correlation between interventricular septal thickness at end diastole and Tricuspid annular plane systolic excursion (TAPSE), Fractional area change (FAC %), Systolic TV annular velocity (S') of the RV using Tissue Doppler imaging and Global right ventricular strain using two-dimensional echocardiography (%). TAPSE (mm), FAC (%), S'(cm/s) and 2D-RVGLS (%) are depressed with increasing IVSd in hypertensive group. Also there was statisically significant negative correlation between LV posterior wall thickness at end diastole and Tricuspid annular plane systolic excursion(TAPSE), Fractional area change (FAC %), Systolic TV annular velocity (S') of the RV using Tissue Doppler imaging and Global right ventricular strain using two-dimensional echocardiography(%) **(23)**.

TAPSE(mm), FAC(%), S'(cm/s) and 2D-RVGLS (%) were depressed with increasing LVPWd in hypertensive group.The concept of early impairment of RV longitudinal mechanical function in the course of hypertensive disease is reinforced by the work of **Tadic et al. (24)** in which strain-assessed RV longitudinal function was shown to be affected, not only in subjects with sustained hypertension but also in white-coat hypertension cases, despite the normal RV wall thickness and Doppler-derived indices in the latter group.

This study covered a small number of patients. The accuracy of 2D RV strain for RV performance remains unclear. Because the definitive speckle-tracking software for the right ventricle has not yet been developed, we used a speckle-tracking program for LV strain to assess RV strain. However, other investigators have recently used a speckle-tracking program for LV strain to assess RV strain, and they demonstrated that the feasibility and the reproducibility of RV strain were acceptable. Patient's refusal to join our study.

Conclusion:

The findings of this research indicated that the development of right ventricular dysfunction in patients with systemic hypertension has been associated with adverse outcomes. Thus, the assessment of RV function has become increasingly important in the management of patients with systemic hypertension. In clinical practice, therefore, a visual assessment of RV function is performed most often.

The current conventional echocardiographic techniques can be used to estimate RV performance, but the quantification of RV function remains a challenge because of the complex geometry of the chamber.

Regarding the hypertensive group, TAPSE, S' velocity, FAC,and RV GLS, were impaired by different degrees in the whole population and this means that the efficacy of these parameters as diagnostic tools is different and suggest that we may be underestimating the prevalence of RV injury in our hypertensive population if we only use classical echocardiographic parameters in order to make the diagnosis of RV infarction.

RV strain parameters measured by 2D-speckle tracking echocardiography have the highest accuracy in detection of RV impairment.

Recommendations

Future studies dealing with a large number of patients are needed to verify the above results and to throw more light onto this important issue. Assessment of the right ventricular functions should be performed routinely to all patients suffering from systemic arterial hypertension. 2D strain & strain rate echocardiography should be considered as an essential part of routine echocardiography in patients suffering from systemic arterial hypertension.

More effort should be exerted in the near future to solve the technical problems and pitfalls of the strain and strain rate imaging. Changes in the software may be needed to improve the tracking ability of the speckle tracking system for future RV functionality studies. Because some patients had different values of RV strains from the basal, middle, and apical regions because of regional RV dysfunction.

Ethics approval and consent to participate

A written consent approved by the local Ethical Research Committee at Menoufia faculty of Medicine was signed by every participant prior to the study initiation. Institutional Review Board was also obtained. All coauthors are aware and approve the contents of the submitted manuscript.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgements

Not applicable.

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