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ORIGINAL ARTICLE

Ventricular Functions in Congenital Heart Diseases: A Tissue Doppler Study

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Abstract

Background: Congenital heart diseases (CHD) account for one third of all congenital anomalies. Doppler and Tissue Doppler evaluate cardiac performance and diagnose CHD. Study aim: evaluation ventricular functions in congenital heart diseases using tricuspid plane systolic excursion TAPSI and tissue Doppler-derived left ventricular myocardial performance index MPI. **Methods:** The study was performed at Pediatric Cardiology Unit of Zagazig University Hospitals on 70 age and sex matched children classified into case group included 35 patients with CHD and control group included 35 healthy children underwent complete history, conventional echocardiographic and tissue Doppler examination.

Results: There was increase in cases regarding interventricular septum (IVS) and decrease in left ventricular diameter at end diastole (LVDd), left ventricular diameter at end systole (LVDs), right pulmonary artery diameter (RPA) and left atrium diameter more than control group with no difference in between regarding: posterior wall diameter (PW), fractional shortening (FS), main pulmonary artery diameter, left pulmonary artery diameter (LPA) and aorta diameter. There was a highly significant decrease in TAPSE in case more than control group and significant decrease in ejection time (ET) with no significant difference between case and control group regarding LV MPI.

Conclusions: TAPSE is lower in cases compared with control group indicating longitudinal RV dysfunction. The value of LV MPI was slightly higher than that of control that need further studies with a larger number of patients.LV FS did not show any abnormality in cases pointing out ability of tissue Doppler echocardiography to measure segmental LV dysfunction compared to conventional echocardiography.

Key words: ventricular functions; CHD; tissue Doppler; TAPSE; MPI.

INTRODUCTION

Congenital heart diseases (CHD) can be subdivided into two major groups: acyanotic group and cyanotic group [1]. Congenital heart diseases are that type of diseases that often need treatment over life especially in children, and need further follow up by a specialist especially when developed serious heart defects concerning heart rhythm or problems including the valves of the heart [2]. When myocardial cells are exposed to volume or pressure overloads, damage begins to occur in terms of necrosis, apoptosis and mechanical stressors that may cause direct pressure and stretching of myocardium leading to cellular damage which may contribute to clinical deterioration. For patients with CHD, it is important to determine the degree of the damage in the myocardium besides detecting the presence of heart failure and its severity [3].

Diagnosis of congenital heart diseases employ different modalities. Tissue Doppler modality is an important investigating methods and it is a robust echocardiographic technique helping in quantification of global and regional myocardial contractile function in addition to ventricular relaxation. Tissue Doppler measurements have the advantage being a powerful prognostic markers in different cardiovascular conditions [4].

This study aimed to evaluate the ventricular functions in congenital heart diseases using tricuspid annular plane systolic excursion (TAPSE) and tissue Doppler-derived left ventricular myocardial performance index (MPI).

METHODS

This cross-sectional study was carried out at Pediatric Cardiology Unit and Pediatric Echocardiography Unit of Zagazig University Hospitals from January 2019 to December 2019. Written informed consent was obtained from all participants, the study was approved by the research ethical committee of Faculty of Medicine, Zagazig University. The study was done according to The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Patients:

This study was performed on 70 age and sex-matched children who were classified into two groups: Group 1 (case group), this group included 35 patients who had congenital heart diseases and they were 16 females and 19 male with ages ranged from (2 months -11years). We had 35 cases of CHD including AS, AR, ASD, VSD, PDA, bilateral branch pulmonary artery stenosis, coarctation of Aorta, tetralogy of Fallot, MS, MR, PR, PS and left ventricular outflow tract obstruction.

Group 2 (control group): this group included 35 healthy children, matching with group 1 in age and sex, they were 11 females and 24 males with age ranged from (4 months -12 years). The members of group 2 were selected from children examined at Echocardiography laboratory of Pediatric Cardiology Unit who turned out to have normal cardiac anatomy.

Inclusion criteria: Children aged less than 11 years. Children with congenital heart diseases either acyanotic or cyanotic. Exclusion criteria: Patients who were outside the age group mentioned. Patients with myocarditis, cardiomyopathies and myocardial ischemia. Patients with heart failure.

Administrative design: This study was approved by the Institutional Review Board (IRB) of Faculty of Medicine, Zagazig University Hospital.

Methods:

All children participating in this study were subjected to:

Complete history taking including: Name, age, sex, current complaint and previous complaints such as pallor, cholestasis, fever, omphalocele, pneumonia and respiratory distress or operations. Cholestasis may be accompanied with branch pulmonary artery stenosis in Alagille syndrome. Patients with omphalocele have an increased risk of CHD.

Complete physical examination: General examination including: weight, respiratory rate, heart rate and blood pressure. Local examination to heart chest and abdomen for organomegaly.

Echocardiographic and tissue Doppler examinations were performed by the same operator using a My lab Six (Esáote) machine using a 3-11 S transducer. Simultaneous ECG recording was performed. Echocardiographic measurement was carried out according to the recommendation of the American Society of Echocardiography [5].

Conventional echocardiography; Aortic (AO) and left atrial (LA) dimensions were measured from the parasternal short axis view. The main pulmonary artery, right and left pulmonary branches diameters were measured from the parasternal short axis view. Interventricular septum (IVS), left ventricular posterior wall (LVPW) thickness, left ventricular end diastolic (LVEDd) and left ventricular end systolic (LVESd) dimensions were measured from the parasternal short axis view. At the end of diastole, the septal wall thickness, posterior LV wall thickness and the diastolic diameter of the left ventricle were measured by 2D echocardiography [6].

Conventional LV systolic functions: The left ventricular end diastolic (LVED) and left ventricular end systolic (LVES) dimensions parameters were measured from M-mode (MM) images in parasternal short axis views just below the level of the mitral valve [6].

Fractional shortening (FS) was calculated through M-mode: FS (%) = (LVEDd – LVESd)/LVEDd×100 (where LVEDd is left ventricular end diastolic dimension, LVESd is the left ventricular end systolic dimension) [7].

Pulmonary artery mean pressure of more than 25mmHg at rest was considered as pulmonary hypertension [8].

Tricuspid Annular Plane Systolic Excursion (TAPSE): TAPSE was measured from apical 4-chamber view. Using M-mode Echocardiography, the absolute longitudinal displacement of the lateral tricuspid annulus was obtained [9].

Tissue Doppler echocardiography; TDE-derived LV myocardial performance index (MPI): The time interval from cessation of mitral inflow in one cardiac cycle to onset of mitral inflow in the subsequent cycle including: Isovolemic contraction time (IVCT): from the beginning of the first positive deflection after the Q-wave to the onset of the S-wave. Aortic ejection time (ET): was measured from the beginning to the end of the S-wave. Isovolemic relaxation time (IVRT): from the end of the S-wave to the beginning of E-wave. Myocardial performance index (MPI): combining systolic and diastolic time intervals were calculated as the sum of IVCT+ET+IVRT-ET divided by ET. Tissue Doppler evaluation was done in apical four-chamber view with the pulsed-wave Doppler sample volume of 3 mm placed at the medial and lateral annulus of mitral valve. We used the average of the two recordings for each parameter in statistical analysis." [10].

STATISTICAL ANALYSIS

The collected data were coded, entered, presented, and analyzed by computer using a database software program, Statistical Package for Social Science (SPSS) version 20.

Qualitative data were represented as frequencies and percent and Chi square (X^2) test was used to detect the relation between different qualitative variables.

For quantitative variables mean ± standard deviation (SD) (for normally distributed data) and median with range (for not normally distributed data) were computed and Independent t-test (t) was used for detection of difference between different quantitative variables, while nonparametric data was evaluated with Mann-Whitney U test.

Kruskal Wallis was used to compare between more than two groups of non-normally distributed variables.

The results were considered statistically significant and highly statistically significant when the significant probability (P value) was < 0.05 and <0.001 respectively.

RESULTS

Patients who had congenital heart diseases (case group) were with median age 9 months while control group were with median age 9 months. There was a statistically significant increase (P< 0.05*) in case group in comparison to control group regarding pulse and respiratory rate and a statistically significant decrease in weight, while there were no statistically significant difference (P≥ 0.05) between them regarding systolic blood pressure and diastolic blood pressure (Table 1).

Table 2, shows that (48.5%) of case group didn't have other clinical problems and the most common presenting problem was tachycardia which was found in 22.9% of patients besides, pneumonia and respiratory distress that were also frequent and occurred in 11.4% of patients

There was a statistically significant increase (P< 0.05) in case group in comparison to control group regarding IVS and there were statistically significant decrease regarding LVDd, and LVDs while there was no statistically significant difference (P≥ 0.05) between them regarding PW and FS (Table 3).

There were a statistically significant decrease (P< 0.05) in case group in comparison to control group regarding diameters of right pulmonary artery and left atrium, while there were no statistically significant difference (P≥ 0.05) between them regarding the diameters of main pulmonary artery, left pulmonary artery and aorta (Table 4).

There was highly statistically significant decrease in case group in comparison to control group regarding TAPSE and ET while there was

statistically significant increase regarding IVRT+ET+IVCT, but there was no statistically significant difference between them regarding MPI (Table 5).

Table 1: Clinical characteristics of the studied participants (n=70):

Variables	Case group (n=35)	Control group (n=35)	Test value	P value
Pulse (min): Mean± SD	129.66±13.99	120.97±17.29	2.310	[c]0.024*
Respiratory rate (min): Mean± SD	42.63±9.00	38.63±5.60	2.232	[c]0.030*
Systolic blood pressure (mmHg): Mean± SD	107.29±14.26	111.57±12.88	-1.319	[c]0.191
Diastolic blood pressure (mmHg): Mean± SD	77.57±8.08	79±8.12	0.738	[c]0.463
Weight (Kg): Median (Range)	7 (3.5 - 35)	12 (6 - 48)	-3.021	[a]0.004*

[a] Mann–Whitney U test-[b] Chi square test (X^2) - [c]Independent sample student t- Test

Table 2: Distribution of case group according to the presence of other clinical problems:

Other problems	No=35	%
No medical problem other than CHD	17	48.5
Pallor	2	5.7
Cholestasis	1	2.9
Fever	1	2.9
Omphalocele	2	5.7
Pneumonia	4	11.4
Pulmonary hypertension	2	5.7
Respiratory distress	4	11.4
Tachycardia	8	22.9

Table 3: Conventional echo findings among the studied participants (n=70):

Variables	Case group (n=35)	Control group (n=35)	Test value	P value
IVS(mm): Mean± SD	8.21±2.7	6.71±1.87	2.702	[a]0.009*
LVDd(mm): Mean± SD	25.28±8.30	31.15±7.70	-3.067	[a]0.003*
LVDs(mm): Mean± SD Median (Range)	15.63±6.15 14 (6.1 - 29)	24.41±17.77 19 (12 - 90)	-2.762	[c]0.008*
PW(mm): Mean± SD	6.65±2.01	7.61±2.62	-1.713	[c]0.091
FS (%): Mean± SD	37.54±10.08	40±6.98	-1.185	[c]0.240

[a] Mann–Whitney U test - [c] Independent t- Test

EF: ejection fraction- FS: fractional shortening -IVS: inter ventricular septum -LVDd: left ventricular diameter at diastole -LVDs: left ventricular diameter at systole –PW: posterior wall.

Table 4: Conventional echo findings among the studied participants (n=70):

Variables	Case group (n=35)	Control group (n=35)	Test value	P value
Main Pulmonary Artery Diameter(mm): Mean± SD	14.29±4.39	15.35±3.94	-1.026	[c]0.309
Right pulmonary artery Diameter (mm): Mean± SD Median (Range)	6.51±2.68 5.5 (3 - 13)	8.12±2.19 8 (5 - 12)	-2.695	[a]0.009*
Left pulmonary artery diameter(mm): Mean± SD Median (Range)	5.80±2.95 6 (2 - 16)	6.66±2.50 7 (4 - 12)	-1.282	[a]0.204
Aorta diameter(mm): Mean± SD Median (Range)	16.18±5.44 15 (9.6 - 39)	17.95±3.82 17.5 (13 - 28)	-1.541	[a]0.128
Left atrium diameter (mm): Mean± SD	18.79±4.20	20.94±3.88	-2.156	[c]0.036*

[a] Mann–Whitney U test - [c] Independent t- Test .

Table 5: Tissue Doppler and TAPSE parameters among the studied participants

Variables	Case group (n=35)	Control group (n=35)	Test value	P value
ET(ms): Mean± SD	206.06±44.74	354.34±59.65	-3.371	[c]0.001*
(IVRT+ET+IVCT)(ms): Mean± SD	306.86±60.97	129.66±13.99	-3.293	[c]0.002*
Left ventricle MPI : Mean±SD	0.506±0.2	0.476±0.1	0.721	[c] 0.47
TAPSE (mm): Mean± SD	13.63±4.64	17.64±3.98	3.883	[c]<0.001**

[a] Mann–Whitney U test -[c] Independent sample student t- Test

- ET : ejection time -IVCT : isovolemic contraction time -IVRT: isovolemic relaxation time -mm: millimeter- MPI : myocardial performance index- MS: millisecond- TAPSE : tricuspid annular plane systolic excursion .

DISCUSSION

Our case group included 16 females and 19 males while in control there were 11 healthy females and 24 healthy males. The age of patients ranged from 2 months to 11years while that of control ranged from 4 months to 12 years. There was no statistically significant difference between case and control groups regarding age and sex; ensuring homogeneity of both groups.

When comparing between the two studied groups according to some clinical characteristics there was statistically significant difference as there were tachycardia and tachypnea more in case group than control group denoting the effect of CHD on the vital signs because of loading condition either volume and/or pressure overload and state of lung congestion [11].

This is in agreement with Tripathi et al. [12] who made a retrospective study on patients with CHD and found that 6.5 % of his patients had supraventricular tachycardia and it was significantly more likely to occur in patients age ≤12 months or in adolescents ≥13 years.

There was no statistically significant difference between case and control group regarding systolic blood pressure and diastolic blood pressure. However, Ahmad.[13] recorded symptoms of peripheral (non-pulmonary) congestion in his studied patients with acute heart failure especially in right side heart failure where there is isolated right ventricular (RV) dysfunction that produced elevated peripheral systemic venous pressures denoting the effect of cardiovascular disease on the hemodynamic state.

In our study, there was statistically significant decrease in case group in comparison to control

group regarding weight and this agrees with Cheung et al. [14] who found patients with CHD showed significantly lower mean weight and height than the control group.

Failure of growth is common problem in patients with congenital cardiac malformations, and can be related to congestive heart failure and/or hypoxia and with repairing of simple lesions there is reverse of that retardation in growth. That could be declared by many explanations, as hemodynamic disturbances, higher basal metabolic rates, in addition, decreased caloric intake. The degree of growth impairment is found not always to correlate with the severity of the cardiac lesion [15].

In our study, seventeen of our patients (48.5%) had no clinical problems other than CHD. The most common presenting problem was tachycardia in (22.9%). Pneumonia and respiratory distress were found in (11.4%). While there were less frequent problems such as pallor and omphalocele in (5.7%) for each. Cholestasis and fever were found in (2.9%) for each. The most common clinical presentations in Shah et al. [16] were failure to thrive (FTT) and developmental delay (86.9%), breathlessness (69%), lower respiratory tract infection (LRTI) (52%), congestive cardiac failure (CCF) (46%), cyanotic spell (9.5%) and infective endocarditis (9.5%).

There were two participants in case group out of 35 cases had pulmonary hypertension (5.7%). This comes in contradict with Gaafar et al. [17] who found that 16.6% of cases (8 out of 48 cases) developed mild pulmonary hypertension and showed that small PDA, Fallot tetralogy and membranous VSD are the highest congenital cardiac lesions among the studied children (16.7%, 12.5% and 10.4 % respectively) and regarding cyanotic cardiac lesions, Fallot tetralogy is found 3 times more than TGA.

Conventional echo techniques help in assessing the changes in cardiac cavity dimension and the speed of blood stream that named as shortening fraction (FS), ejection fraction (EF), and blood pool analysis in the other hand, tissue Doppler directly assesses muscle wall characteristics, such as velocity and deformation that is become an advantage over the old conventional one [18]

On investigating our participants using echo, there was a statistically significant increase in case group than control group regarding interventricular septum (IVS) and statistically significant decrease regarding left ventricular diameter at end diastole (LVDd), left ventricular diameter at end systole (LVDs), right pulmonary artery diameter (RPA) and left atrium diameter. Our study showed no statistically significant difference between case and control group regarding: posterior wall diameter (PW) main pulmonary artery diameter, left pulmonary artery diameter (LPA) and aorta diameter. There was no statistically significant difference between case and control groups regarding fractional shortening (FS).

LVDd, LVDs and RPA also were significantly increased in patients who underwent TOF repair declaring this Shehata et al. [19] who explained the difference by the pathophysiology of TOF which is characterized by reduced pulmonary blood flow, hence an untrained left ventricle.

Pauliks et al. [20] studied ASD patients versus normal control and found that LVEDd was significantly smaller and the FS was less than in controls, which probably was secondary to the abnormal septal motion in the ASD patient group. All patients with ASD had at least mild right-sided heart enlargement.

TAPSE is a cardiographic method that depends on application of tricuspid annular plane excursion to analyze right ventricular systolic function that makes it easy to be evaluated in adult and children [21].

There was a highly statistically significant decrease of TAPSE in case more than control group indicating RV dysfunction in our patients with CHD. This result agreed with Shehata et al. [19] who found that 80% of the patients(30 children who underwent TOF repair) had TAPSE less than 20 attributed to the fact of pulmonary regurge causes volume overload of the RV with subsequent dilatation and dysfunction in cases of TOF. Also, this was declared by Ho et al. [22] who showed in their study that patients with severe pulmonary regurge had a mean TAPSE of 18.5 ± 3.2 m.

Koestenberger et al. [23] detected no significant difference in TAPSE values in control subjects and age-matched ASD patients. The TAPSE was not decreased compared to normal subjects in eight infants TOF patients before corrective surgery.

In our study there was a statistically significant decreased in ejection time (ET) in patients with CHD compared to control.

MPI is considered a good method for evaluating LV systolic and diastolic function together and is calculated by using pulsed-wave tissue Doppler modalities [24].

In our study, there was no significant difference between LV MPI between patients with CHD and healthy participants although the absolute value of LV MPI was slightly higher in patients. This coincides with Eidem et al. [25] who

declared that the RV MPI for pediatric patients with ASD was not statistically different from that of normal children. However, in adults with longstanding volume overload due to ASD, the RV MPI was slightly but significantly increased compared with normal adults.

In addition, our study disagrees with Shahlaee et al. [26] whose study was designed to define normal values for myocardial performance index (MPI) in children and to evaluate the utility of MPI in congenital heart disease. The right ventricular (RV) and left ventricular (LV) MPI were measured in 152 normal children (ages 3 to 18 years) and 45 preoperative patients with Ebstein anomaly. They found that both RV and LV MPI were abnormally increased in the Ebstein group with increasing RV dysfunction.

Yasuoka et al. [27] examined 15 patients with tetralogy of Fallot (TOF) and 24 age-matched healthy children. Pulsed Doppler–Tei index and TDI–Tei index were measured. The Tei index obtained by the pulsed Doppler method in TOF patients did not differ from that in normal children with no significance. TDI showed that both IVCT and IVRT in TOF patients were significantly longer than those in normal children. So, the Tei index as measured by TDI was significantly greater in TOF patients than in normal children.

CONCLUSIONS

TAPSE is significantly lower in patients with CHD compared with control group indicating longitudinal right ventricular dysfunction in our patients.

The fact that the absolute value of LV tissue Doppler-derived MPI was slightly higher in patients than in control subjects, although no statistically significant difference was found, probably reflects the need for further studies with a larger number of patients to evaluated the presence or absence of LV systolic and diastolic dysfunction in CHD patients. LV fractional shortening did not show any abnormality in our cases which may point out the ability of tissue Doppler echocardiography to measure segmental LV dysfunction compared to conventional echocardiography.

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