AIM OF THE WORK

The aim of this work was to assess right ventricular functions in patients with bronchial asthma using tissue Doppler strain rate measurement. Correlate it with the severity of asthma attacks.

SUBJECTS

The subjects were divided into two groups from the main university hospital (cardiology and chest diseases departments):

1) **Group I:** This group includes fifteen Patients with bronchial asthma.
2) **Group II:** This group includes age and sex matched fifteen non asthmatic healthy subjects as control group.

Inclusion criteria:

- Chronic bronchial asthma.
- In between attacks
- Age interval from 20 – 40 years.

Exclusion criteria:

- Patients with cardiac arrhythmia.
- Patients with myocardial ischemia.
- Patients with significant vulvular heart disease.
- Patients with cor-pulmonale.
- Patients with diabetes mellitus.
- Patients with hypertension.

METHODS

Group I were subjected to:

1- Plain-X-ray chest and heart (P-A) to exclude other chest condition.
2- Resting electrocardiography (E.C.G) standard twelve lead E.C.G for assessing the degree of right ventricular hypertrophy, any conduction defects or axis deviation.
3- Arterial blood gases.
4- Spirometry (FEV1, FEV1% of predicted value)

To classify patients according to FEV1, FEV1% of predicted value into mild cases and moderate to severe cases of bronchial asthma.

All subjects were subjected to:

1- Informed concent will be obtained.
2- Complete clinical examination including:
   a- Complete history taking, stressing on age, duration of bronchial asthma, anti asthmatic treatment, the presenting symptoms.
   b- General examination, pulse, blood pressure, chest examination.
   c- Cardiac examination stressing on signs of pulmonary hypertension, right ventricular enlargement.
3- Echocardiography

I. Conventional Echocardiography

- RV dimensions: RV dimension is best estimated at end-diastole from a right ventricle–focused apical 4-chamber view. Care should be taken to obtain the image demonstrating the maximum diameter of the right ventricle without foreshortening. This can be accomplished by making sure that the crux and apex of the heart are in view. Diameter > 42 mm at the base and > 35 mm at the mid level indicates RV dilatation. Similarly, longitudinal dimension > 86 mm indicates RVenlargement.[91]
- RVOT fractional area change: Two-dimensional FAC (as a percentage) provides an estimate of RV systolic function. Two-dimensional FAC < 35% indicates RV systolic dysfunction. It is important to make sure that the entire right ventricle is in

the view, including the apex and the lateral wall in both systole and diastole. Care must be taken to exclude trabeculations while tracing the RV area.[92]

- ❖ TAPSE: TAPSE is easily obtainable and is a measure of RV longitudinal function. TAPSE < 16 mm indicates RV systolic dysfunction. It is measured from the tricuspid lateral annulus. Although it measures longitudinal function, it has shown good correlation with techniques estimating RV global systolic function, such as radionuclide-derived RV EF, 2D RV FAC, and 2D RV EF.[92]
- ❖ IVC diameter with inspiratory collapse:It is to assess RV diastolic function. Right atrial pressure (RAP) is estimated by examining the inferior vena cava (IVC) size (normal = 5 mmHg, dilated but compressible during inspiration = 10 mmHg and dilated and noncompressible = 15 mmHg).[93]If IVC is decreased by 50% or more, the right atrial pressure is less than 10 mmHg from subcostal view.[94]
- ❖ RV myocardial performance index

RIMP provides an index of global RV function. RIMP > 0.40 by pulsed Doppler and > 0.55 by tissue Doppler indicates RV dysfunction. By measuring the isovolumic contraction time (IVCT), isovolumic relaxation time (IVRT), and ejection time (ET) indices from the pulsed tissue Doppler velocity of the lateral tricuspid annulus, one avoids errors related to variability in the heart rate. RIMP can be falsely low in conditions associated with elevated RA pressures, which will decrease the IVRT.[92]

II. Doppler flow

Pulmonary artery pressure (PAP) from TR if present: The most reliable method for estimating pulmonary artery systolic pressure noninvasively is based on measurement of the tricuspid regurgitant jet. This velocity (VTR) reflects the RV to RA pressure difference. When added to an estimate right atrial pressure, RV systolic pressure is obtained. In absence of pulmonic stenosis, RV systolic pressure equals pulmonary artery systolic pressure.

$$\text{PAP systolic} = 4(V_{TR})^2 + \text{RAP}.^{(95)}$$

III. TDI

- ❖ Tricuspid annulus Tissue velocity: It is used to assess RV diastolic function.
- ❖ Mean Systolic strain

S strain rate

Myocardial strain is the percentage of shortening or lengthening of a myocardial segment. Strain rate is the rate at which the myocardium shortens or lengthens. One-dimensional strain is acquired using Doppler tissue imaging and is consequentially angle dependent. It is most reproducible in the apical 4-chamber view, interrogating the basal, mid, and, to a lesser degree, apical segments of the RV free wall. Values for strain and SR are then derived offline on the system or workstation using equipment-specific algorithms by placing sample volume(s) or regions of interest of varying sizes in the mid portion of the segment(s).[96]

In principle, the superiority of deformation parameters for assessing cardiac function compared to motion-velocity-displacement parameters is related to the basic strain-algorithm, which subtracts the motion due to the contraction of neighboring segments (tethering effects and translational motion). Completely passive segments can show motion relative to the transducer due to tethering, but without any deformation, making velocity and displacement information completely unreliable for the characterization of such regions. Strain parameters on the other hand, are referred to as motion-deformation between two points in the myocardial wall, which is unrelated to the motion towards the transducer, and this fact discriminates the actual passive movement from true contraction in any myocardial region. Color Doppler myocardial imaging has been used as a clinical and research tool for estimating deformation parameters with high spatial accuracy. The actual spatial resolution depends on many technical issues, but generally falls at best in the range from 1 to 5 mm.[80]

Statistical analysis of the data

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0.

Qualitative data were described using number and percent. Quantitative data were described using minimum and maximum, mean and standard deviation and median.

Comparison between different groups regarding categorical variables was tested using Chi-square test. When more than 20% of the cells have expected count less than 5, correction for chi-square was conducted using Fisher's Exact test.

The distributions of quantitative variables were tested for normality using Kolmogorov-Smirnov test, Shapiro-Wilk test and D'Agstino test, also Histogram and QQ plot were used for vision test. If it reveals normal data distribution, parametric tests was applied. If the data were abnormally distributed, non-parametric tests were used.

For normally distributed data, comparison between the two groups were done using independent t-test while more than two population were analyzed F-test (ANOVA) to be used. For abnormally distributed data, comparison between the two groups done using Mann Whitney test while Kruskal Wallis test was used to compare between different groups .

Significance of the obtained results was judged at the 5% level.

RESULTS

The present study was conducted at Alexandria main university hospital, Cardiology and chest departments.

Demographic data:

The study included 30 individuals divided into two groups,

- Group I: 15 bronchial asthma patients {1 (6.7%) male and 14 (93.3%) females}
- Group II: 15 healthy control subjects {1 (6.7%) male and 14 (93.3%) females}

The age of both groups ranged between 20 and 40 years. The mean age of bronchial asthma patients was 35.07± 6.58 years. While, the mean age of healthy control subjects was 32.20±4.80 years. The mean weight of bronchial asthma patients was 74.53± 17.82 kg. while, the mean weight of healthy control subjects was 68.47±10.80 kg. The mean height of bronchial asthma patients was 156.73±4.25 cm. and the mean height of healthy control subjects was 160.07±5.73cm. The mean BMI of bronchial asthma patients was 30.17± 6.26 kg/m^2. While, the mean BMI of healthy control subjects was 26.92± 5.25 kg/m^2 as shown in table (2)**.**

Table (2): Comparison between the studied groups according to demographic data.

	Bronchial asthma patients (n=15)		Control (n=15)		Test of Sig.	P
	No.	%	No.	%		
Sex						
Male	1	6.7	1	6.7	χ^2=0.0	^{FE}p=1.000
Female	14	93.3	14	93.3		
Age (years)						
Min. – Max.	20.0 – 40.0		22.0 – 40.0			
Mean ± SD.	35.07 ± 6.58		32.20 ± 4.80		t=1.363	0.185
Median	40.0		33.0			
Weight (kg)						
Min. – Max.	49.0 – 101.0		58.0 – 86.0			
Mean ± SD.	74.53 ± 17.82		68.47 ± 10.80		t=1.128	0.271
Median	76.0		64.0			
Height (cm)						
Min. – Max.	148.0 – 162.0		150.0 – 173.0			
Mean ± SD.	156.73 ± 4.25		160.07 ± 5.73		t=1.810	0.081
Median	156.0		159.0			
BMI (kg/m^2)						
Min. – Max.	20.93 – 39.45		19.38 – 36.26			
Mean ± SD.	30.17 ± 6.26		26.92 ± 5.25		t=1.545	0.134
Median	31.25		24.54			

p: p value for comparing between the two studied groups

Symptoms and duration of bronchial asthma:

Patients with bronchial asthma had duration of disease between 4 and 20 months with a mean of 9.48± 5.65months. Patients presented with symptoms of cough, dyspnea or both with percentage of 13.3%, 33.3%, and 53.3% respectively. About 66.7% of patients were compliant with regular medical treatment of bronchial asthma while 33.3% of them were not compliant with medications as shown in table (3).

Table (3): Distribution of studied sample according to symptoms, duration bronchial asthma and medication in bronchial asthma patients (n=15).

	No.	%
Symptoms		
Cough	2	13.3
Dyspnea	5	33.3
Both	8	53.3
Duration of Bronchial asthma (months)		
Min. – Max.	4 – 20.0	
Mean ± SD.	9.48 ± 5.65	
Median	10.0	
Medication		
No	5	33.3
Yes	10	66.7

History of other allergy:

In the study 6.7% of asthmatic patients had a history of sinusitis while 93.3% had no history of other allergy. Meanwhile, 100% of healthy control subjects had no history of sinusitis nor other allergy as shown in table (4).

Table (4): Comparison between the studied groups according to other allergy and other diseases

	Bronchial asthma patients (n=15)		Control (n=15)		χ^2	^{FE}p
	No.	%	No.	%		
Other allergy						
No	14	93.3	15	100.0	1.034	1.000
Sinusitis	1	6.7	0	0.0		
Other diseases	0	0.0	0	0.0	-	-

Blood Pressure &Pulse:

The mean value of pulse of bronchial asthma patients and healthy control group was 84.47±9.68 bpm, 70.07±6.76 bpm respectively with significance difference between two groups according to pulse as $p<0.05$.

Bronchial asthma patients group had mean systolic pressure 114.67±9.90mmgh while mean systolic pressure of healthy control group was 114.67±9.15mmgh. With no statistically significant difference between both groups $p > 0.05$. Bronchial asthma patients group had mean diastolic pressure 72.67±4.58mmgh, while mean diastolic pressure of healthy control group was 74.0±5.07. With no statistically significant difference between both groups $p > 0.05$ as shown in table (5).

Table (5): Comparison between the studied groups according to blood pressure and pulse

	Bronchial asthma patients (n=15)	Control (n=15)	t	P
Pulse (bpm)				
Min. – Max.	65.0 – 100.0	70.0 – 88.0		
Mean ± SD.	84.47 ± 9.68	77.07 ± 6.76	2.428*	0.022*
Median	84.0	80.0		
Systolic (mmHg)				
Min. – Max.	100.0 – 130.0	100.0 – 130.0		
Mean ± SD.	114.67 ± 9.90	114.67 ± 9.15	0.0	1.000
Median	120.0	120.0		
Diastolic (mmHg)				
Min. – Max.	70.0 – 80.0	70.0 – 80.0		
Mean ± SD.	72.67 ± 4.58	74.0 ± 5.07	0.756	0.456
Median	70.0	70.0		

Different clinical parameters:

In the study, 40% of asthmatic patients presented with wheezes on clinical examination and 20% of them had audible TR as shown in table (6).

Table (6): Comparison between the studied groups according to different parameters

	Bronchial asthma patients (n=15)		Control (n=15)		χ^2	^{FE}p
	No.	%	No.	%		
Wheezes	6	40.0	0	0.0	7. 500*	$^{FE}p=0.017$*
Accentuated P2	0	0.0	0	0.0	-	-
TR	3	20.0	0	0.0	3.333	$^{FE}p=0.224$
RVE	0	0.0	0	0.0	-	-
ECG	0	0.0	0	0.0	-	-

0: no abnormalities

Blood gases analysis of bronchial asthma patients:

In the study the mean of PH was 7.40 ± 0.02 and mean of PCO2 (mmHg) was 37.45 ± 2.92. Also the mean of PO2 (mmHg) was 93.57 ± 6.57 and mean of O2Sat% was 96.03 ± 1.56 as shown in table (7).

Table (7): Descriptive blood gases analysis of bronchial asthma patients (n=15)

	Min. – Max.	Mean ± SD.	Median
PH	7.37 – 7.47	7.40 ± 0.02	7.40
PCO_2(mmHg)	27.70 – 40.0	37.45 ± 2.92	38.0
PO_2 (mmHg)	75.0 – 107.60	93.57 ± 6.57	94.0
O_2 sat. %	94.0 – 98.50	96.03 ± 1.56	96.0

FEV1% of bronchial asthma patients

In the study, bronchial asthma patients classified as mild, moderate and severe according to FEV1% of predicted value with percentage of 20%, 40% and 40% respectively with mean 67.96 ± 14.20 % as shown in table (8).

Table (8): Descriptive analysis of studied sample according to FEV1% in bronchial asthma patients group (n=15)

	No.	%
FEV1%		
Mild (>80)	3	20.0
Moderate (60 - 80)	6	40.0
Severe (<60)	6	40.0
Min. – Max.	45.76 – 86.26	
Mean ± SD.	67.96 ± 14.20	
Median	72.84	

Echocardiographic evaluation of RV diameters

RVOT diameters:

In the study, the mean RVOT (max. diameter) of bronchial asthma patients and healthy control subjects was (30.27 ± 5.07 mm, 30.37 ± 4.52 mm) respectively. With no statistically significant difference between both group ($p > 0.05$). The mean RVOT (min. diameter) of bronchial asthma patients and healthy control subjects was (18.75 ± 3.37 mm, 18.27 ± 3.0 mm) respectively with no statistically significant difference between both groups ($p > 0.05$) as shown in table (9). There was no statistically significant difference between different severity of bronchial asthma patients group ($p>0.05$) as shown in table (10).

Table (9): Comparison between the studied groups according to RVOT diameters.

	Bronchial asthma patients (n=15)	Control (n=15)	t	P
RVOT(max.diamter) mm				
Min. – Max.	20.90 – 38.0	20.0 – 37.0		
Mean ± SD.	30.27 ± 5.07	30.37 ± 4.52	0.053	0.958
Median	31.0	30.0		
RVOT(min.diamter) mm				
Min. – Max.	12.50 – 24.0	12.70 – 23.0		
Mean ± SD.	18.75 ± 3.37	18.27 ± 3.0	0.412	0.683
Median	18.0	18.0		

Table (10): Relation between severity of bronchial asthma patients group and RVOT diameters

	According toFEV1%			F	p
	Mild (>80) (n = 3)	Moderate (60 - 80) (n = 6)	Severe (<60) (n = 6)		
RVOT(max.diamter) (mm)					
Min. – Max.	23.80 – 34.0	25.0 – 34.0	20.90 – 38.0		
Mean ± SD.	27.93 ± 5.37	30.0 ± 3.90	31.72 ± 6.27	0.534	0.599
Median	26.0	31.0	33.20		
RVOT(min.diamter) (mm)					
Min. – Max.	12.50 – 16.80	15.0 – 24.0	16.50 – 24.0		
Mean ± SD.	15.27 ± 2.40	18.67 ± 3.14	20.58 ± 2.87	3.328	0.071
Median	16.50	18.0	21.0		

F: F test (ANOVA)

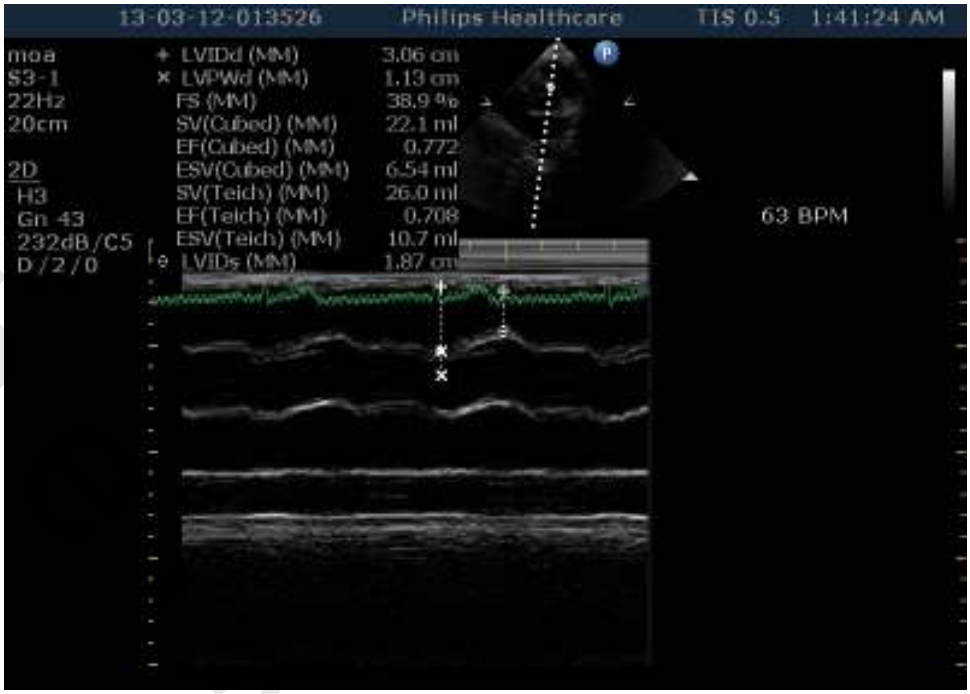

Figure (9): RVOT diameters &RV FAC of a healthy control subject

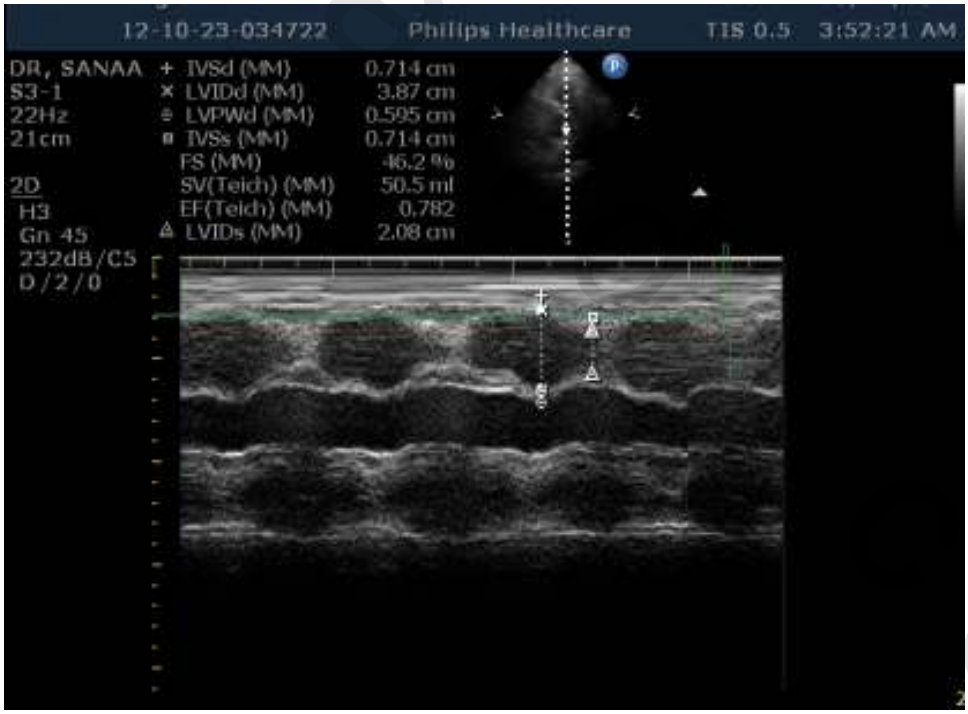

Figure (10): RVOT diameters &RV FAC of bronchial asthma patient:

RV FAC, TAPSE:

In the study, the mean RV FAC of bronchial asthma patients and healthy control subjects was (37.75 ± 9.03 %, 40.33 ± 3.05 %) respectively with no significant difference (p>0.05). The mean TAPSE of bronchial asthma patients and healthy control subjects was (22.47 ± 3.75 mm, 22.15 ± 1.33 mm) respectively with no statistically significant difference (p>0.05) as shown in table (11). There was no statistically significant difference between different severity of bronchial asthma patients group (p>0.05) as shown in table (12).

Table (11): Comparison between the studied groups according to RV FAC and TAPSE

	Bronchial asthma patients (n=15)	Control (n=15)	t	P
FAC %				
Min. – Max.	21.80 – 48.30	36.0 – 45.90		
Mean ± SD.	37.75 ± 9.03	40.33 ± 3.05	1.046	0.310
Median	43.0	39.0		
TAPSE (mm)				
Min. – Max.	16.0 – 26.60	20.40 – 24.60		
Mean ± SD.	22.47 ± 3.75	22.15 ± 1.33	0.311	0.759
Median	23.60	22.0		

Table (12): Relation between different severity of bronchial asthma patients group and FAC and TAPSE

	According to FEV1%			F	p
	Mild (>80) (n = 3)	Moderate (60 - 80) (n = 6)	Severe (<60) (n = 6)		
FAC%					
Min. – Max.	43.0 – 47.60	32.0 – 48.30	21.80 – 46.0		
Mean ± SD.	44.53 ± 2.66	40.05 ± 6.11	32.07 ± 10.74	2.805	0.100
Median	43.0	41.50	29.80		
TAPSE(mm)					
Min. – Max.	23.60 – 26.60	17.0 – 25.90	16.0 – 26.60		
Mean ± SD.	25.40 ± 1.59	22.65 ± 3.71	20.82 ± 4.02	1.644	0.234
Median	26.0	24.50	20.90		

F: F test (ANOVA)

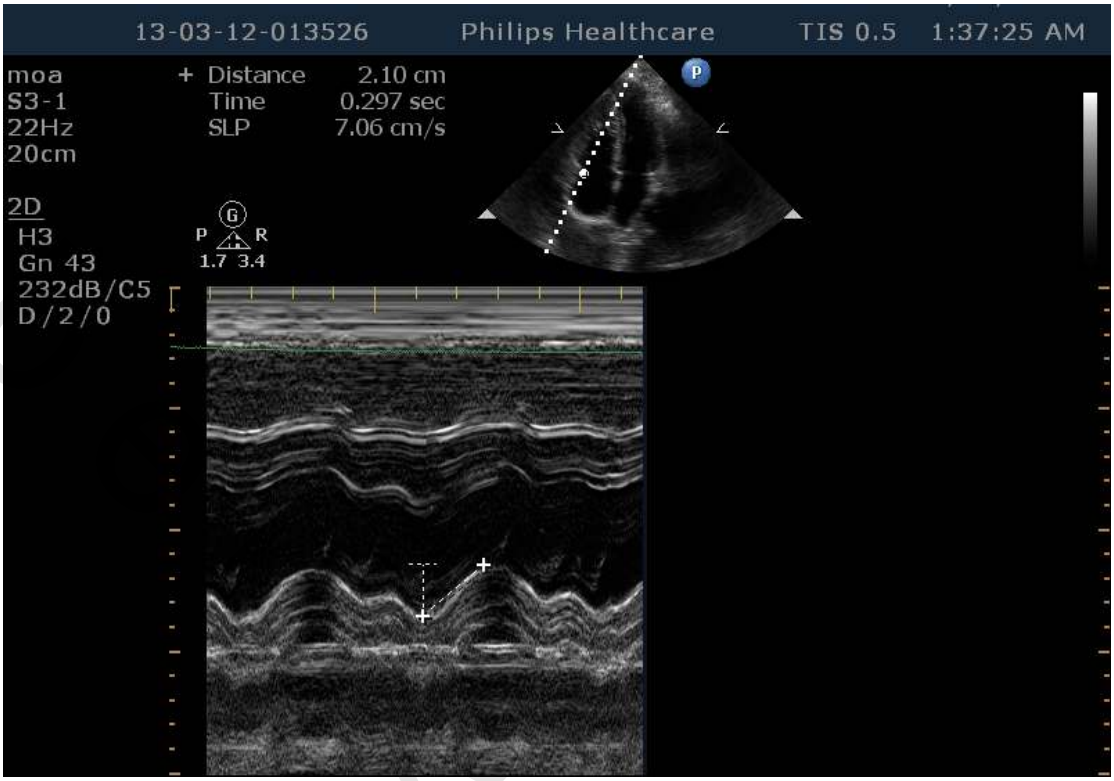

Figure (11): TAPSE of healthy control subject:

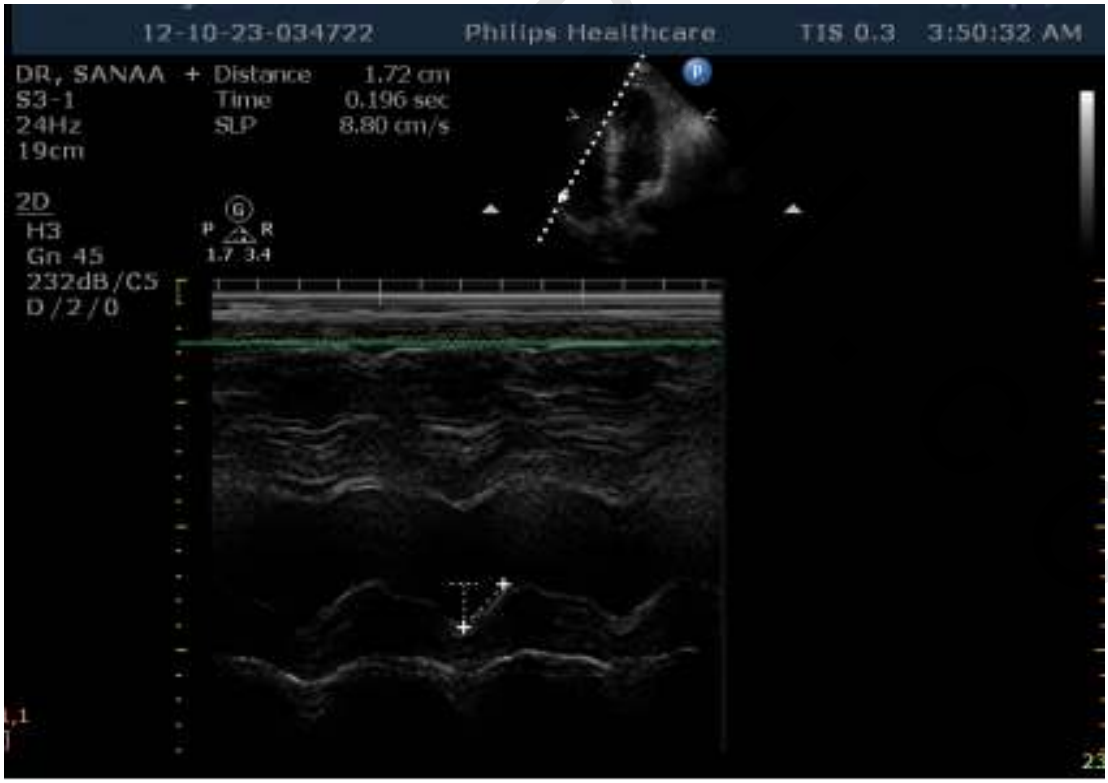

Figure (12): TAPSE of bronchial asthma patient:

IVC measurement:

In the study, the mean IVC expiration diameter of bronchial asthma patients and healthy control subjects was (14.02 ± 3.68 mm, 13.34 ± 2.36 mm) respectively with no statistically significant difference (p> 0.05). The mean IVC inspiration diameter of bronchial asthma patients and healthy control subjects was (8.37 ± 3.29 mm, 6.89 ± 1.98 mm) respectively with no statistically significant difference (p> 0.05). The mean IVC% collapse of bronchial asthma patients and healthy control subjects was (41.40 ± 12.36 %, 50.40 ± 11.19 %) respectively with statistically significant difference between two groups (p <0.05) as shown in table (13). There was no statistically significant difference (p>0.05) between different severity of bronchial asthma according to IVC measurement as shown in table (14).

Table (13): Comparison between the studied groups according to IVC measurement

	Bronchial asthma patients (n=15)	Control (n=15)	Z	p
IVC(expiration) mm				
Min. – Max.	6.0 – 18.0	7.0 – 16.0		
Mean ± SD.	14.02 ± 3.68	13.34 ± 2.36	1.316	0.188
Median	15.0	13.0		
IVC(inspiration) mm				
Min. – Max.	2.70 – 13.40	2.0 – 9.0		
Mean ± SD.	8.37 ± 3.29	6.89 ± 1.98	1.367	0.172
Median	8.0	6.0		
IVC %collapse				
Min. – Max.	25.50 – 75.0	38.70 – 86.0		
Mean ± SD.	41.40 ± 12.36	50.40 ± 11.19	2.722*	0.006*
Median	40.0	50.0		

Table (14): Relation between different severity of bronchial asthma patients group and IVC measurement

	FEV1%			$^{KW}\chi^2$	p
	Mild (>80) (n = 3)	**Moderate (60 - 80) (n = 6)**	**Severe (<60) (n = 6)**		
IVC(expiration)(mm)					
Min. – Max.	6.0 – 18.0	11.0 – 18.0	6.30 – 17.0		
Mean ± SD.	12.33 ± 6.03	14.83 ± 2.32	14.05 ± 3.93	0.431	0.806
Median	13.0	15.0	15.50		
IVC(inspiration)(m)					
Min. – Max.	3.50 – 13.0	6.0 – 13.40	2.70 – 12.0		
Mean ± SD.	8.17 ± 4.75	9.40 ± 2.55	7.45 ± 3.53	1.069	0.586
Median	8.0	9.0	8.0		
IVC %collapse					
Min. – Max.	27.70 – 41.60	25.50 – 45.40	29.40 – 75.0		
Mean ± SD.	35.90 ± 7.28	37.48 ± 7.57	48.07 ± 16.11	2.379	0.304
Median	38.40	40.0	44.70		

$^{KW}\chi^2$: Kruskal Wallis test

1. Doppler study of RV :

TV inflow

In the study, the mean TV flow (E) of bronchial asthma patients, healthy control subjects was (50.82 ± 9.24 mm/s, 49.33 ± 6.32 mm/s) respectively. The mean TV flow (A) of bronchial asthma patients, healthy control subjects was (54.65 ± 8.09 mm/s, 51.84 ± 5.30 mm/s) respectively. The mean TV flow E/A of bronchial asthma patients, healthy control subjects was (0.94 ± 0.19, 0.95 ± 0.10) respectively. The mean TV deccl. time of bronchial asthma patients, healthy control subjects was (189.0 ± 71.42 ms, 178.93 ± 37.50 ms) respectively as shown in table (15). There was no statistically significant difference between different severity of bronchial asthma (p>0.05) as shown in table (16).

Table (15): Comparison between the studied groups according to TV inflow Doppler study

	Bronchial asthma patients (n=15)	Control (n=15)	Test of sig.	p
TV flow (E) mm/s				
Min. – Max.	35.0 – 67.0	40.0 – 58.0		
Mean ± SD.	50.82 ± 9.24	49.33 ± 6.32	t=0.514	0.611
Median	52.0	50.0		
TV flow (A) mm/s				
Min. – Max.	35.80 – 68.0	40.0 – 58.0		
Mean ± SD.	54.65 ± 8.09	51.84 ± 5.30	t=1.127	0.269
Median	54.0	51.0		
TV flow E/A				
Min. – Max.	0.70 – 1.22	0.83 – 1.11		
Mean ± SD.	0.94 ± 0.19	0.95 ± 0.10	t=0.207	0.838
Median	0.88	0.96		
TV deccl time ms				
Min. – Max.	94.0 – 331.0	115.0 – 256.0		
Mean ± SD.	189.0 ± 71.42	178.93 ± 37.50	Z=0.249	0.803
Median	182.0	165.0		

Table (16): Relation between different severity of bronchial asthma patients group and TV inflow Doppler study

	According to FEV1%			Test of sig.	p
	Mild (>80) (n = 3)	**Moderate (60 - 80) (n = 6)**	**Severe (<60) (n = 6)**		
TV flow (E)(mm/s)					
Min. – Max.	47.0 – 59.0	35.0 – 58.0	39.0 – 67.0		
Mean ± SD.	54.67 ± 6.66	48.27 ± 8.99	51.45 ± 11.10	F= 0.465	0.639
Median	58.0	48.50	50.35		
TV flow (A) (mm/s)					
Min. – Max.	53.0 – 67.0	48.0 – 68.0	35.80 – 63.0		
Mean ± SD.	59.33 ± 7.09	54.83 ± 7.11	52.13 ± 9.58	F= 0.768	0.486
Median	58.0	53.50	52.0		
TV flow E/A					
Min. – Max.	0.88 – 1.0	0.70 – 1.20	0.71 – 1.22		
Mean ± SD.	0.92 ± 0.07	0.88 ± 0.19	1.01 ± 0.23	F= 0.623	0.553
Median	0.88	0.81	1.10		
TV deccl time(ms)					
Min. – Max.	148.0 – 182.0	94.0 – 283.0	111.0 – 331.0		
Mean ± SD.	164.0 ± 17.09	178.67 ± 74.84	211.83 ± 86.23	$^{KW}\chi^2$= 0.839	0.657
Median	162.0	185.50	216.0		

$^{KW}\chi^2$: Kruskal Wallis test

F: F test (ANOVA)

TR, peak S gradient and PA accel.time (m sec):

In the study, 40% of bronchial asthma patients had mild TR with mean peak S gradient was (14.50 ± 4.42 m/s^2) while 6.7% of healthy control subjects had mild TR with mean peak S gradient was (7-12 m/s^2). The mean PA accel. time (ms) of bronchial asthma patients, healthy control subjects was (125.8 ± 44.44 ms, 128.67 ± 18.75 ms) respectively as shown in table (17).

Table (17): Comparison between the studied groups according to TR, peak S gradient and PA accel.time (m sec)

	Bronchial asthma patients (n=15)		Control (n=15)		Test of Sig.	p
	No.	%	No.	%		
TR						
No	9	60.0	14	93.3	χ^2=4.658	^{FE}p=0.080
Mild	6	40.0	1	6.7		
Peak S gradient (m/s^2)	**(n = 6)**		**(n = 1)**			
Min. – Max.	8.0 – 20.0					
Mean ± SD.	14.50 ± 4.42		7-12		t=0.314	0.766
Median	13.50					
PA accel. time (ms)						
Min. – Max.	57.0 – 182.0		100.0 – 175.0			
Mean ± SD.	125.8 ± 44.44		128.67 ± 18.75		Z=0.021	0.983
Median	130.0		125.0			

2. Tissue Doppler study of RV:

RVPI

In the study, the mean RVPI (IVCT) of bronchial asthma patients and healthy control subjects was (57.67 ± 18.87 ms, 53.20 ± 5.65 ms) respectively. The mean RVPI (IVCT) of bronchial asthma patients groups (mild, moderate, severe) was (53.67±15.28 ms, 52.17±15.75 ms, 65.17±23.29 ms) respectively. There was significant difference between two groups according to RVPI(IVRT) with mean of bronchial asthma patients, healthy control subjects was (277.40 ± 57.18 ms, 206.40 ± 44.63 ms) respectively, as $p \leq 0.05$.There was significant difference between bronchial asthma patients groups (mild, moderate, severe) according to RVPI(IVRT) with mean (237.33±25.03 ms, 324.17±41.49 ms, 250.67±52.32 ms) respectively. The mean RVPI (ET) of bronchial asthma patients, healthy control subjects was (67.07 ± 31.32 ms, 62.33 ± 15.49 ms) respectively. The mean RVPI (ET) of bronchial asthma patients groups (mild, moderate, severe) was (43.67±11.93 ms, 83.0±39.31 ms, 62.83±22.14 ms) respectively as shown in table (18,19).

Table (18): Comparison between the studied groups according to RV tissue Doppler parameters.

	Bronchial asthma patients (n=15)	Control (n=15)	Test of sig.	P
RVPI(IVCT) (ms)				
Min. – Max.	30.0 – 94.0	47.0 – 62.0		
Mean ± SD.	57.67 ± 18.87	53.20 ± 5.65	t=0.878	0.393
Median	57.0	53.0		
RVPI(IVRT) (ms)				
Min. – Max.	196.0 – 378.0	107.0 – 281.0		
Mean ± SD.	277.40 ± 57.18	206.40 ± 44.63	t=3.791*	0.001*
Median	273.0	216.0		
RVPI(ET) (ms)				
Min. – Max.	30.0 – 137.0	44.0 – 81.0		
Mean ± SD.	67.07 ± 31.32	62.33 ± 15.49	Z=0.083	0.934
Median	57.0	60.0		

Table (19): Comparison between the studied groups according to RVPI

	Mild ">80" (n=3)	Moderate "60 – 80" (n=6)	Severe "<60" (n=6)	Test of Sig.	P
RVPI-IVCT (ms)					
Min. – Max.	37.0-67.0	30.0-67.0	40.0-94.0		
Mean ± SD.	53.67±15.28	52.17±15.75	65.17±23.29	F=0.770	0.485
Median	57.0	56.0	62.50		
RVPI-IVRT (ms)					
Min. – Max.	213.0-263.0	273.0-378.0	196.0-334.0		
Mean ± SD.	237.33±25.03	324.17±41.49	250.67±52.32	F=5.664*	0.019*
Median	236.0	313.50	244.50		
Pairwais comp.	II-III*				
RVPI-ET (ms)					
Min. – Max.	34.0-57.0	51.0-137.0	30.0-88.0		
Mean ± SD.	43.67±11.93	83.0±39.31	62.83±22.14	χ^2=2.612	0.271
Median	40.0	64.0	65.50		

TDI TV:

In the study, there was significant difference between two groups according to TDI TV (E) with mean of bronchial asthma patients, healthy control subjects was (133.13 ± 27.66 mm/s, 166.73 ± 30.65 mm/s) respectively as $p \leq 0.05$. There was significant difference between two groups according to TDI TV (A) with mean of bronchial asthma patients, healthy control subjects was (119.20 ± 25.59 mm/s, 166.73 ± 41.75 mm/s) respectively as $p \leq 0.05$. The mean TDI TV (S) of bronchial asthma patients, healthy control subjects was (170.67 ± 61.25 mm/s, 144.13 ± 45.61mm/s) respectively as shown in table (20). There was no statistically significant difference between different severity of bronchial asthma ($p>0.05$) as shown in table (21).

Table (20): Comparison between the studied groups according to TDI TV

	Bronchial asthma patients (n=15)	Control (n=15)	Test of sig.	P
TDI TV (E) (mm/s)				
Min. – Max.	93.0 – 186.0	125.0 – 227.0		
Mean ± SD.	133.13 ± 27.66	166.73 ± 30.65	t = 3.152*	0.004*
Median	125.0	180.0		
TDI TV (A) (mm/s)				
Min. – Max.	68.0 – 161.0	124.0 – 238.0		
Mean ± SD.	119.20 ± 25.59	166.73 ± 41.75	t = 3.760*	0.001*
Median	119.0	154.0		
TDI TV (S) (mm/s)				
Min. – Max.	82.0 – 301.0	91.0 – 213.0		
Mean ± SD.	170.67 ± 61.25	144.13 ± 45.61	Z = 1.183	0.237
Median	139.0	120.0		

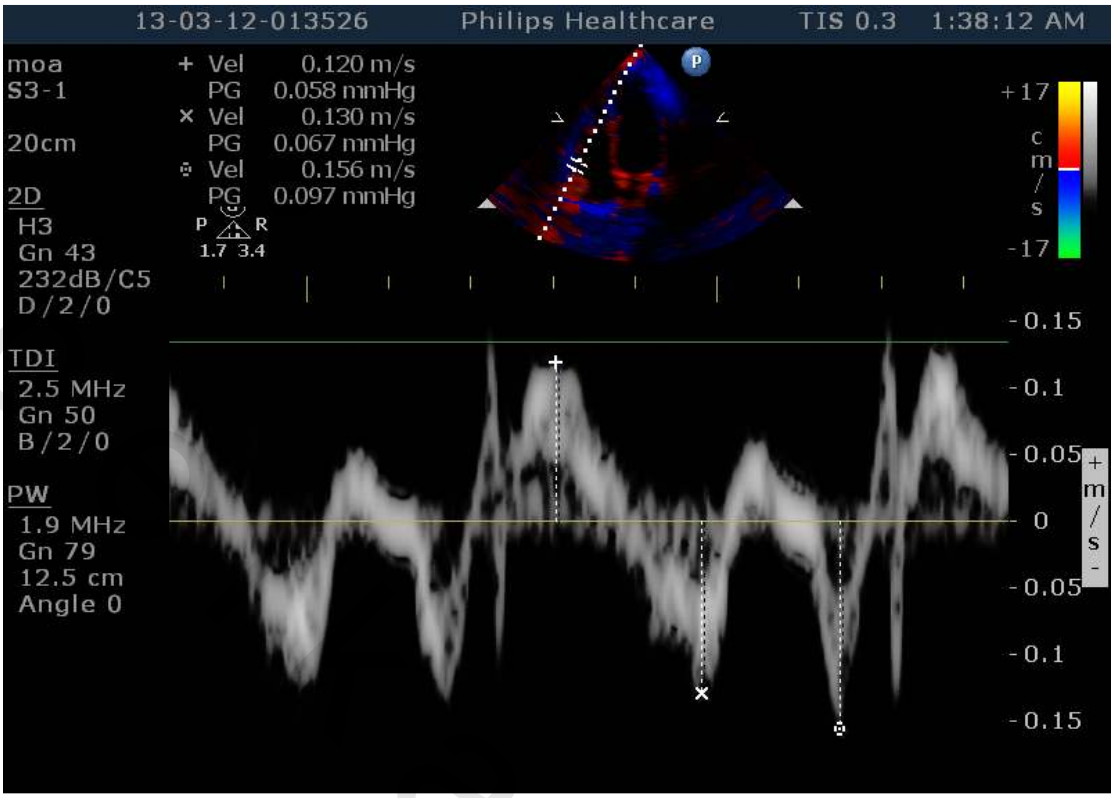

Figure (13): TDI TV of healthy control subject:

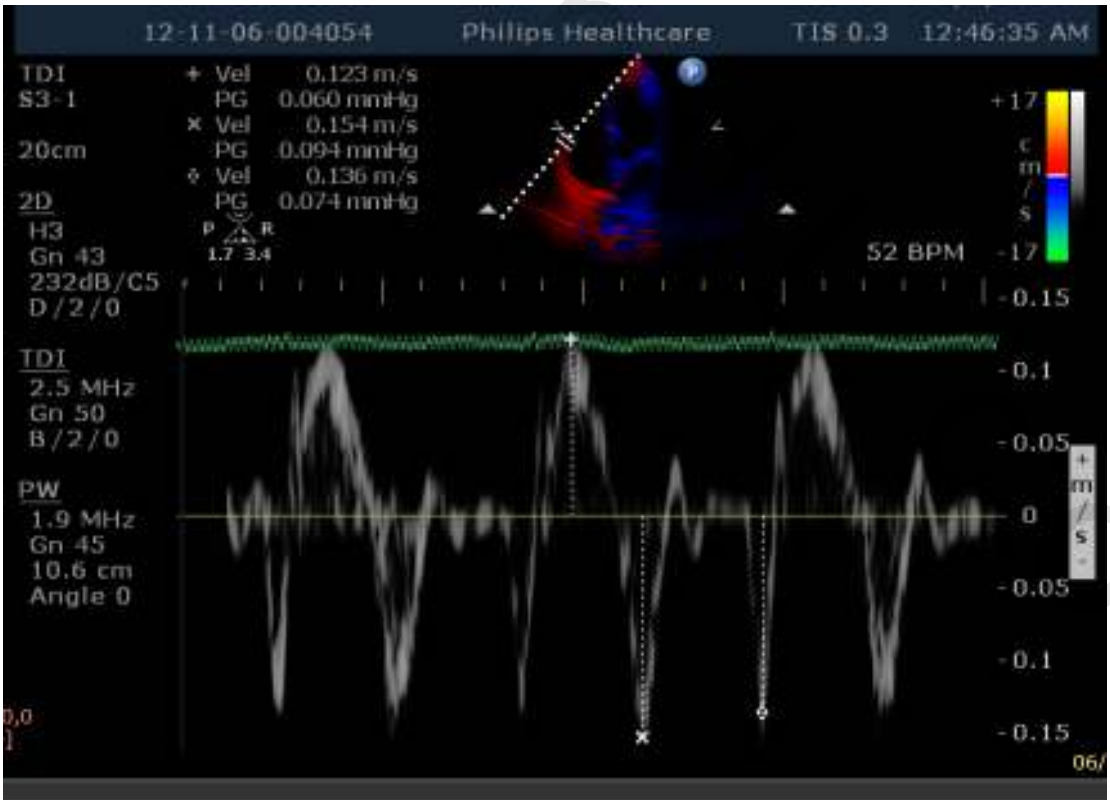

Figure (14): TDI TV of bronchial asthma patient:

Table (21): Relation between different severity of bronchial asthma group and TDI TV

	According to FEV1%			Test of sig.	p
	Mild (>80) (n = 3)	Moderate (60 - 80) (n = 6)	Severe (<60) (n = 6)		
TDI TV (E)					
Min. – Max.	109.0 – 125.0	111.0 – 186.0	93.0 – 181.0		
Mean ± SD.	116.67 ± 8.02	143.0 ± 26.43	131.50 ± 33.68	F=0.913	0.428
Median	116.0	140.50	120.50		
TDI TV (A)					
Min. – Max.	95.0 – 161.0	68.0 – 154.0	84.0 – 143.0		
Mean ± SD.	125.33 ± 33.32	118.33 ± 31.11	117.0 ± 19.79	F=0.097	0.908
Median	120.0	114.0	119.0		
TDI TV (S)					
Min. – Max.	82.0 – 242.0	118.0 – 265.0	130.0 – 301.0	$^{KW}\chi^2$= 0.351	0.839
Mean ± SD.	178.33 ± 84.85	156.67 ± 54.04	180.83 ± 65.66		
Median	211.0	136.0	163.0		

$^{KW}\chi^2$: Kruskal Wallis test
F: F test (ANOVA)

RV strain and strain rate:

In the study, the mean RV (Strain) of bronchial asthma patients, healthy control subjects was (-13.81 ± 0.83 cm/s, -11.53 ± 9.61cm/s) respectively. The mean RV (Strain) of bronchial asthma patients groups (mild, moderate, severe) was (-19.80±1.18 cm/s, -14.62±6.83, -9.99±3.99 cm/s) respectively. The mean RV (Strain rate) of bronchial asthma patients, healthy control subjects was (-2.17 ± 0.83 1/s, -1.87 ± 1.05 1/s) respectively. The mean RV (Strain rate) of bronchial asthma patients groups (mild, moderate, severe) was (-2.78±0.73 1/s, -2.12±0.89 1/s, -1.92±0.78 1/s) respectively as shown in table (22, 23).

Table (22): Comparison between the studied groups according to RV strain and strain rate

	Bronchial asthma patients (n=15)	Control (n=15)	t	P
RV (Strain) (cm/s)				
Min. – Max.	-27.30 - -3.69	-30.64 - -1.90		
Mean ± SD.	-13.81 ± 0.83	-11.53 ± 9.61	0.775	0.446
Median	-2.25	-6.73		
RV (Strain rate) (1/s)				
Min. – Max.	-3.45 - -1.04	-3.90 - -0.97		
Mean ± SD.	-2.17 ± 0.83	-1.87 ± 1.05	0.889	0.382
Median	-2.25	-1.58		

Table (23): Comparison between different severity of bronchial asthma group according to RV strain and RV strain rate.

	Mild ">80" (n=3)	Moderate "60 – 80" (n=6)	Severe "<60" (n=6)	F	P
RV Strain (cm/s)					
Min. – Max.	-20.80 – -18.49	-27.30 – -7.25	-14.90 – -3.69		
Mean ± SD.	-19.80±1.18	-14.62±6.83	-9.99±3.99	3.783	0.053
Median	-20.10	-13.20	-10.14		
RV Strain rate (1/s)					
Min. – Max.	-3.45 – -2.0	-3.10 – -1.04	-2.97 – -1.12		
Mean ± SD.	-2.78±0.73	-2.12±0.89	-1.92±0.78	1.135	0.354
Median	-2.90	-2.28	-1.70		

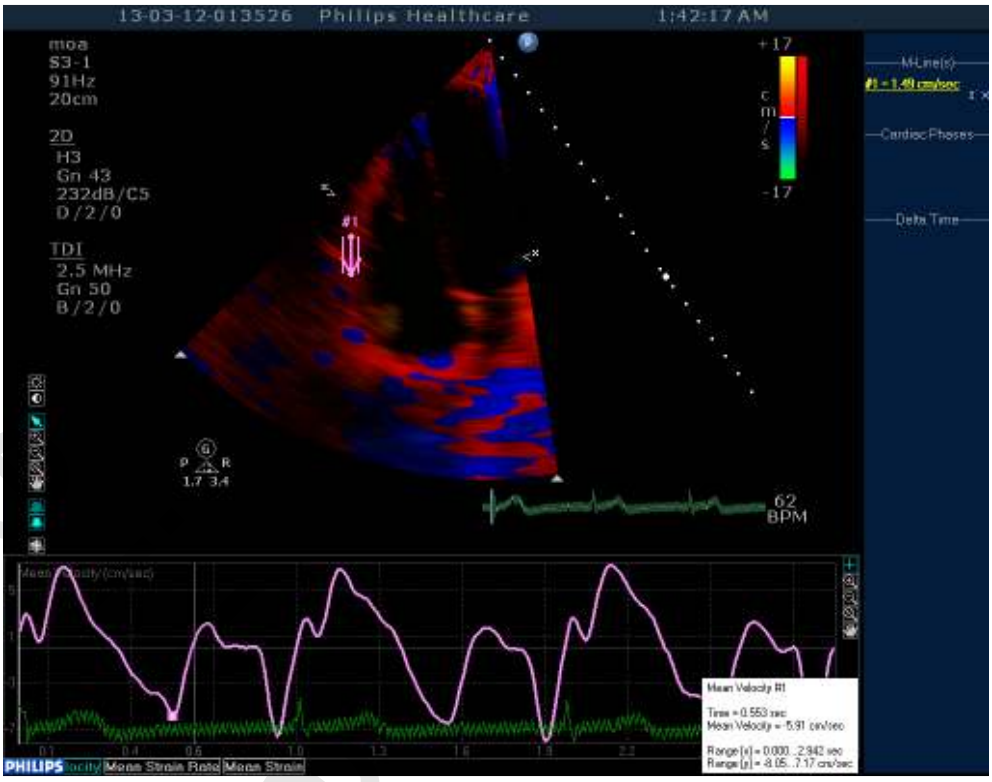

Figure (15): RV strain of healthy control subject

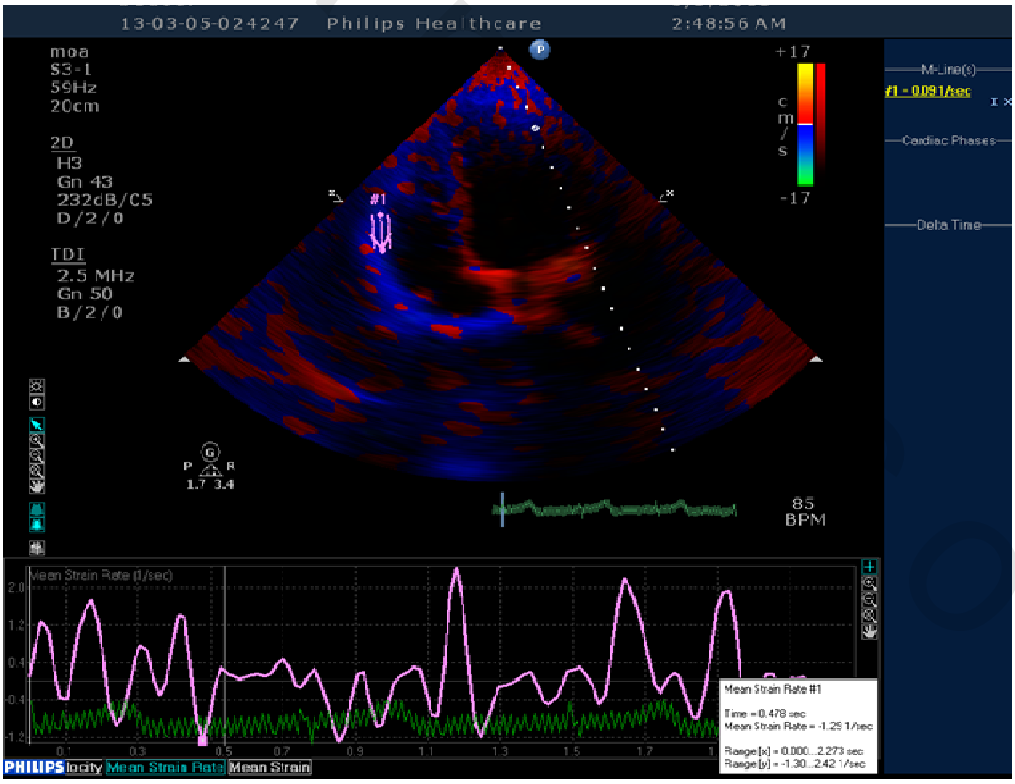

Figure (16): RV strain rate of healthy control subject

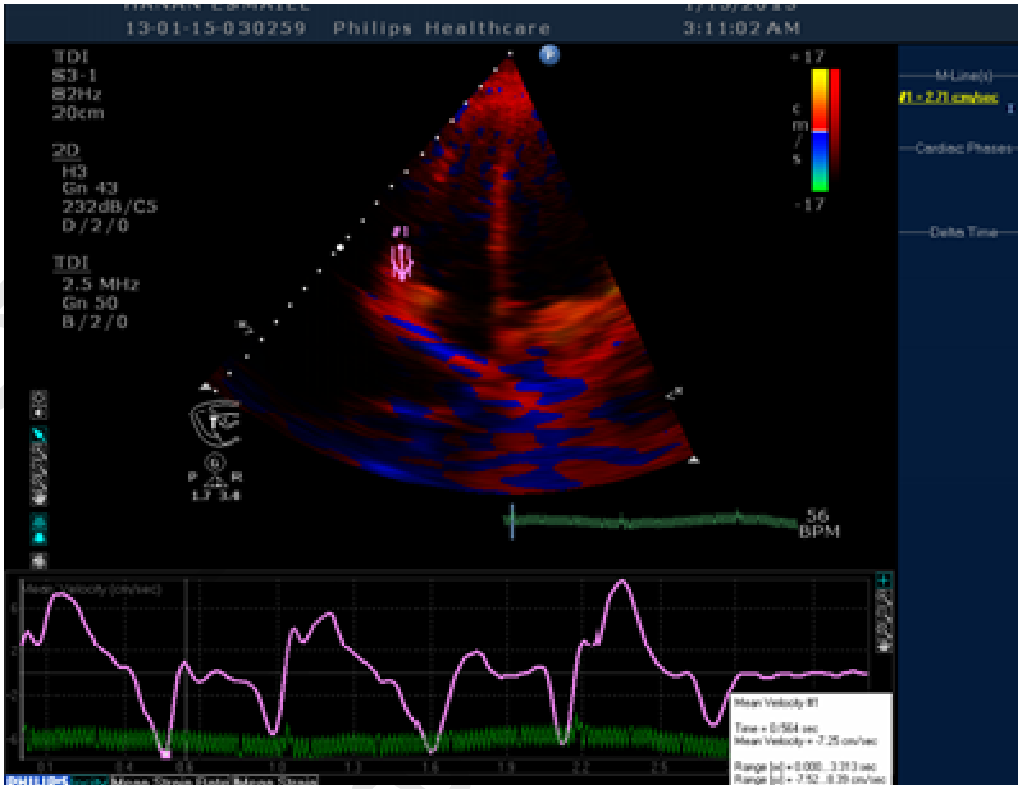

Figure (17): RV strain of bronchial asthma patient

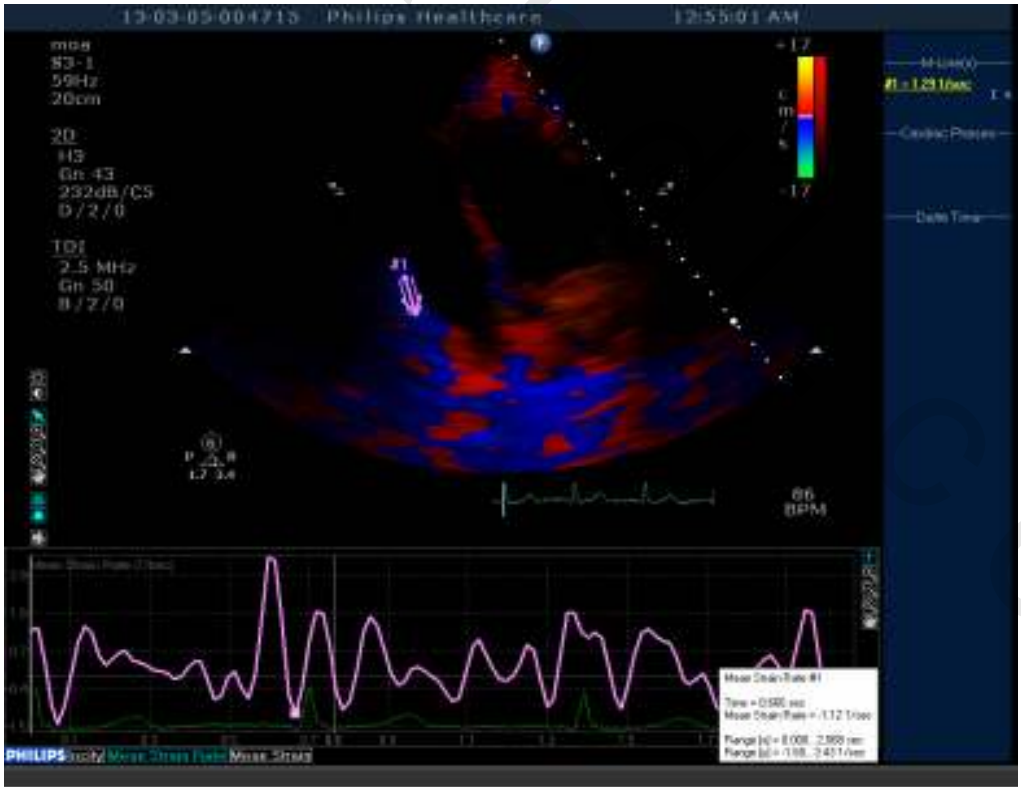

Figure (18): RV strain rate of bronchial asthma patient