

AIM OF THE WORK

To evaluate the left atrial longitudinal myocardial function by strain and strain rate imaging in patients with hypertrophic cardiomyopathy.

PATIENTS

The present study included 40 hypertrophic cardiomyopathy patients in Alexandria Main University hospital ,diagnosed according to the ACCF/AHA Guideline for the Diagnosis and Treatment of Hypertrophic Cardiomyopathy 2011 ⁽²⁰⁾ and 20 healthy control.

- **Group A:** 20 patients with hypertrophic cardiomyopathy without left ventricular outflow obstruction (LVOT gradient less than 30 mmHg at rest)
- **Group B :** 20 patients with hypertrophic cardiomyopathy with left ventricular outflow obstruction (LVOT gradient equal or more than 30 mmHg at rest)
- **Group C:** 20 normal persons (control).

For inclusion:

Based on echocardiography: maximal LV wall thickness ≥ 15 mm , unexplained , associated with nondilated ventricular chambers in the absence of another cardiac or systemic disease that itself would be capable of producing the magnitude of hypertrophy.

Exclusion criteria:

- Significant valvular heart disease.
- Diabetes mellitus.
- Hypertension.
- Ischemic heart disease.
- Heart failure, LV ejection fraction (LVEF) $< 50\%$, New York Heart association functional class III or IV.
- Bundle branch block.
- Atrial fibrillation.
- Inadequate echographic window.

METHODS

All patients were subjected to the following:

1. Full history taking.
2. Complete physical examination.
3. 12-lead ECG to study:
 - ST-T wave changes.
 - Arrhythmia.
 - Bundle branch block

4. Conventional transthoracic echocardiography

Standard 2-dimensional and M-mode echocardiographic studies performed according to the recommendations of the American Society of echocardiography using conventional views and measurements⁽¹⁷⁰⁾, echocardiographic recordings involving 3 consecutive cycles from standard parasternal long-axis and apical 4- and 2-chamber views at a left lateral decubitus position.

- LV mass (LVM) was calculated using the regression equation described by Devereux et al⁽¹⁷⁰⁾, $LVM = 1.04 \times [(IVST + PWT + LVDd)^3 - LVDd^3] - 13.6$, and was corrected to body surface area.
- LVEF by a modified Simpson's formula,⁽¹⁷⁰⁾ tracing of endocardial borders in end-diastole and end-systole was made in the technically best cardiac cycle, and the mean of 3 measurements was used.
- LA dimensions,^(245,246) the LA dimensions measured at the end-ventricular systole when the LA chamber is at its greatest dimension, the anteroposterior diameter measured in the parasternal long-axis view, the superior –inferior diameter measured a long line between the upper point of the superior border of the cavity and the mid-point of the

line joining the attachment points of the mitral leaflets to its ring and the mediolateral diameter measured along the line of maximum distance between the interatrial septum and the lateral boundary of the left atrium.

- The LA volumes, ^(176,202) calculated according to the biplane method from the apical 4- and 2-chamber views just before the mitral valve opening (maximal volume, Vmax), and at the mitral valve closure (minimal volume, Vmin), with exclusion of the pulmonary veins and LA appendage from the LA tracing and the inferior border represented by the plane of the mitral annulus. Then volume index was calculated by dividing the maximal volume on body surface area.
- LVOT gradient by continuous wave Doppler⁽⁴¹⁾, using continuous – wave Doppler maximal instantaneous gradient of LVOT measured with avoidance of signal of the mitral regurgitation jet, both at rest and with provocation with valsalva.
- Transmitral flow using Pulsed wave (PW) Doppler ⁽²⁴⁷⁾, sample volume was placed at the tips of the mitral leaflets by the apical four-chamber view, we measured: Peak early filling velocity (E wave) ,Peak late filling velocity (A wave) , E/A ratio.

5- Tissue Doppler imaging (TDI)

- Pulsed wave tissue Doppler imaging at the lateral mitral annulus, ⁽¹⁸⁸⁾ performed in the apical views to acquire : Peak ventricular systolic velocity (S') , Peak early ventricular diastolic velocity (E') , Peak late ventricular diastolic velocity (A') , E/E'.
- Strain and Strain rate :

For the measurement of deformation indices, the CDMI (conventional and color Doppler myocardial imaging) of the LA was acquired at the apical

4- and 2-chamber views, with a frame rate of 160-200 s⁻¹(²²⁰), the CDMI range setting adapted in order to avoid aliasing within the image. Because of the thin atrial walls, a narrow (10 × 2 mm) sample volume was selected. During this procedure, the narrowest image sector angle (30°) possible used to acquire the maximum frame rate. The evaluated wall was positioned in the center of the window to minimize artificial data and realigned so that the direction of motion interrogated parallel to the direction of the insonating beam. Saved in digital format the 3 consecutive cardiac cycles, then S/Sr and velocity profiles will be extracted (^{202,207,248,249}).

- Longitudinal peak S, Sr measured from the left atrial lateral wall at the end of the reservoir phase (at aortic valve closure), and then Time to peak S and time to peak Sr will be measured.

- Systolic, early diastolic and late diastolic velocities measured from the mid and superior (roof) levels of the LA walls (²⁰⁷), Images of the lateral and septal (medial) walls obtained from the four-chamber View, Anterior and inferior walls from the two-chamber view.

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 range (minimum and maximum), mean, 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 Monte Carlo correction. The distributions of quantitative variables were tested for normality. 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, while more than two population were analyzed F-test (ANOVA) to be used and Post Hoc test (LSD) (Scheffe). For abnormally distributed data, Kruskal Wallis test was used to compare between different groups and pair wise comparison was assessed using Mann-Whitney test. To compare between the different periods Friedman test was applied and Wilcoxon signed ranks test. Significance test results are quoted as two-tailed probabilities. Significance of the obtained results was judged at the 5% level.

RESULTS

The present study was carried out on 60 subjects, they were divided into 3 groups:

Group A (HCM): 20 patients with Hypertrophic cardiomyopathy without left ventricular outlet flow obstruction (LVOT gradient less than 30 mmHg at rest).

Group B (HOCM): 20 patients with Hypertrophic cardiomyopathy with left ventricular outlet flow obstruction (LVOT gradient equal or more than 30 mmHg at rest).

Group C (Control): 20 age and sex matched normal persons as a control.

A- Demographic criteria of the patients and controls (table 3)

Age and Gender: The study included 20 patients with HCM; 14 patients (70%) were males and 6 (30%) were females, their age ranged from 15 to 64 years with a mean of $(38.6 \pm 13.58$ years), 20 patients with HOCCM; 14 patients (70%) were males and 6 (30%) were females, their age ranged from 16 to 65 years with a mean of $(42.7 \pm 12.56$ years) and 20 persons; 12 of them (60%) were males and 8 (40%) were females, their age ranged from 17 to 65 years with a mean of $(35.6 \pm 12.51$ years), there was no significant difference between the three groups in age or gender. (figure 11,12)

The weight in HCM group ranged from 48 to 92 kg with a mean of $(72.8 \pm 8.79$ kg), whereas in HOCCM group the weight ranged from 45 to 96 kg with a mean of $(76 \pm 12.38$ kg) and in the control group the weight ranged from 53 to 92 kg with a mean of $(71.75 \pm 12.44$ kg), there was no significant difference between the three groups.

The height in HCM group ranged from 156 to 175 cm with a mean of $(168.5 \pm 4.61$ cm), whereas in HOCCM group the height ranged from 158 to 178 cm with a mean of $(170.35 \pm 4.5$ cm) and in the control group the height ranged from 155 to 176 cm with a mean of $(166.65 \pm 6.03$ cm), there was no significant difference between the three groups.

The body surface area (BSA) in HCM group ranged from 1.44 to 2.08 kg/m^2 with a mean of $(1.84 \pm 0.13$ kg/m^2), whereas in HOCCM group the BSA ranged from 1.41 to 2.16 kg/m^2 with a mean of $(1.89 \pm 0.17$ kg/m^2) and in the control group the BSA ranged from 1.51 to 2.08 kg/m^2 with a mean of $(1.82 \pm 0.18$ kg/m^2). There was no significant difference between the three groups.

Table (3): Comparison between the three studied groups according to demographic data

	HCM (n = 20)		HOCM (n = 20)		Control (n = 20)		Test of Sig.	p
	No.	%	No.	%	No.	%		
Sex								
Male	14	70.0	14	70.0	12	60.0	$\chi^2=0.600$	0.741
Female	6	30.0	6	30.0	8	40.0		
Age (years)								
Min. – Max.	15.0 – 64.0		16.0 – 65.0		17.0 – 65.0		F=1.528	0.226
Mean ± SD.	38.60 ± 13.58		42.70 ± 12.56		35.60 ± 12.51			
Median	40.0		45.0		32.50			
Sig. bet. grps	p ₁ = 0.606, p ₂ = 0.764, p ₃ = 0.228							
Weight (kg)								
Min. – Max.	48.0 – 92.0		45.0 – 96.0		53.0 – 92.0		F=0.763	0.471
Mean ± SD.	72.80 ± 8.79		76.0 ± 12.38		71.75 ± 12.44			
Median	73.50		75.0		71.0			
Sig. bet. grps	p ₁ = 0.673, p ₂ = 0.958, p ₃ = 0.499							
Height (cm)								
Min. – Max.	156.0 – 175.0		158.0 – 178.0		155.0 – 176.0		F=2.640	0.080
Mean ± SD.	168.50 ± 4.61		170.35 ± 4.50		166.65 ± 6.03			
Median	170.0		170.0		167.50			
Sig. bet. grps	p ₁ = 0.521, p ₂ = 0.521, p ₃ = 0.080							
BSA (kg/m²)								
Min. – Max.	1.44 – 2.08		1.41 – 2.16		1.51 – 2.08		F=1.085	0.345
Mean ± SD.	1.84 ± 0.13		1.89 ± 0.17		1.82 ± 0.18			
Median	1.87		1.90		1.82			
Sig. bet. grps	p ₁ = 0.646, p ₂ = 0.877, p ₃ = 0.355							

BSA= body surface area. *: Statistically significant at $p \leq 0.05$

F: F test (ANOVA) χ^2 : Chi square test

p₁ : p value for Post Hoc test (Scheffe) for comparing between HCM and HOCM

p₂ : p value for Post Hoc test (Scheffe) for comparing between HCM and control

p₃ : p value for Post Hoc test (Scheffe) for comparing between HOCM and control

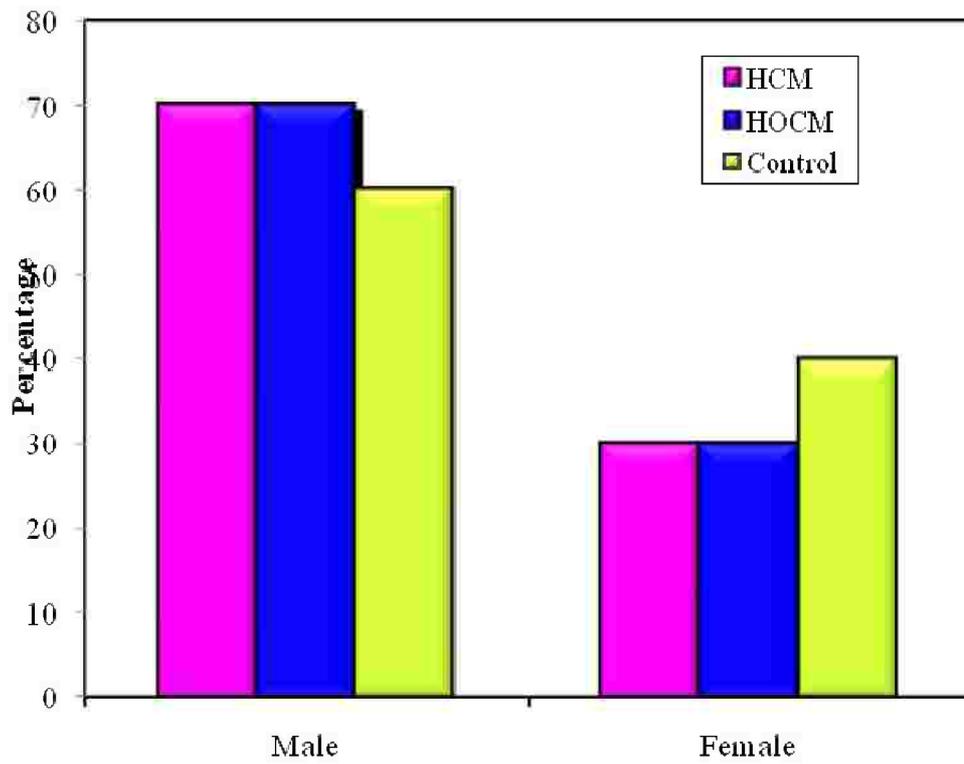


Figure (11): Comparison between the three studied groups according to sex.

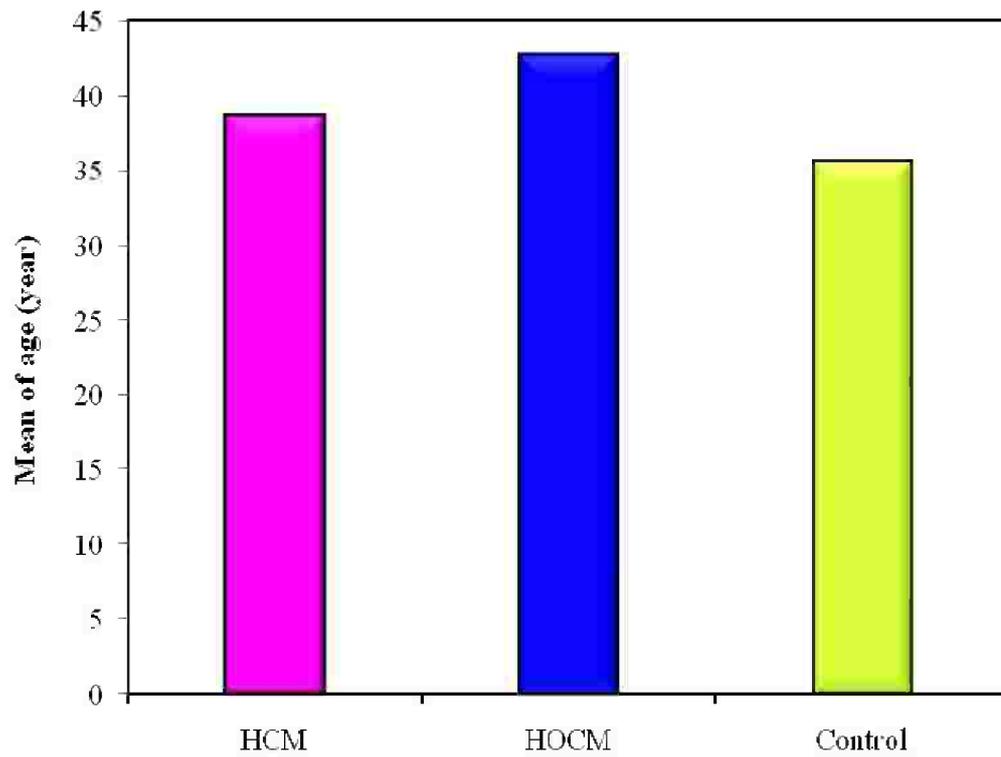


Figure (12): Comparison between the three studied groups according to the age.

B- Vital signs of the patients and controls (table 4)

The systolic blood pressure (SBP) in HCM group ranged from 100 to 140 mmHg with a mean of $(119.75 \pm 10.06 \text{ mmHg})$, whereas the SBP in HOCM group ranged from 100 to 140 mmHg with a mean of $(121.5 \pm 13.77 \text{ mmHg})$ and in the control group the SBP ranged from 100 to 135 mmHg with a mean of $(118.55 \pm 10.4 \text{ mmHg})$, there was no significant difference between the three groups.

The diastolic blood pressure (DBP) in HCM group ranged from 60 to 85 mmHg with a mean of $(75.25 \pm 7.16 \text{ mmHg})$, whereas in HOCM group the diastolic BP ranged from 60 to 90 mmHg with a mean of $(76 \pm 8.37 \text{ mmHg})$,and in the control group the diastolic BP ranged from 60 to 85 mmHg with a mean of $(75 \pm 7.77 \text{ mmHg})$, there was no significant difference between the three groups.

The heart rate in HCM group ranged from 60 to 90 bpm with a mean of $(72.5 \pm 8.22 \text{ bpm})$, whereas in HOCM group the heart rate ranged from 55 to 85 bpm with a mean of $(68.3 \pm 8.26 \text{ bpm})$, and in the control group the heart rate ranged from 60 to 90 bpm with a mean of $(76.7 \pm 8.22 \text{ bpm})$.

There heart rate was significantly lower in HOCM group than in the control group ($p \text{ value} = 0.011$), as most of our patients were receiving either beta blocker or calcium channel blocker

Table (4): Comparison between the three studied groups according to vital signs

	HCM (n = 20)	HOCM (n = 20)	Control (n = 20)	F	p
Systolic BP (mmHg)					
Min. – Max.	100.0 – 140.0	100.0 – 140.0	100.0 – 135.0		
Mean ± SD.	119.75 ± 10.06	121.50 ± 13.77	118.50 ± 10.40	0.341	0.712
Median	120.0	120.0	120.0		
Sig. bet. grps	p ₁ = 0.891, p ₂ = 0.943, p ₃ = 0.714				
Diastolic BP (mmHg)					
Min. – Max.	60.0 – 85.0	60.0 – 90.0	60.0 – 85.0		
Mean ± SD.	75.25 ± 7.16	76.0 ± 8.37	75.0 ± 7.77	0.087	0.917
Median	80.0	80.0	75.0		
Sig. bet. grps	p ₁ = 0.956, p ₂ = 0.995, p ₃ = 0.923				
Heart rate (BPM)					
Min. – Max.	60.0 – 90.0	55.0 – 85.0	60.0 – 90.0		
Mean ± SD.	72.50 ± 8.22	68.30 ± 8.26	76.70 ± 8.90	4.925*	0.011*
Median	71.0	70.0	75.50		
Sig. bet. grps	p ₁ = 0.300, p ₂ = 0.300, p ₃ = 0.011*				

F: F test (ANOVA)

p₁ : p value for Post Hoc test (Scheffe) for comparing between HCM and HOCM

p₂ : p value for Post Hoc test (Scheffe) for comparing between HCM and control

p₃ : p value for Post Hoc test (Scheffe) for comparing between HOCM and control

*: Statistically significant at p ≤ 0.05

C- 12 lead electrocardiography(ECG) (table 5)

In HCM group 25% had ECG changes (precisely LVH criteria) versus 15% in HOcm group and 0% in the control group.

The ECG changes (precisely LVH criteria) were present in HCM group significantly more than the control group (p value =0.047), as in table (8).

Table (5): Comparison between the three studied groups according to ECG Changes.

	HCM (n = 20)		HOcm (n = 20)		Control (n = 20)		χ^2	MC p
	No.	%	No.	%	No.	%		
ECG								
No LVH	15	75.0	17	85.0	20	100.0	5.698	0.081
LVH	5	25.0	3	15.0	0	0.0		
Sig. bet. grps	p ₁ = 0.695, p ₂ = 0.047*, p ₃ = 0.231							

χ^2 : Value for chi square

MC: Monte Carlo test

p₁ : p value for chi square test for comparing between HCM and HOcm

p₂ : p value for chi square test for comparing between HCM and control

p₃ : p value for chi square test for comparing between HOcm and control

*: Statistically significant at p ≤ 0.05

ECG (electrocardiogram).

LVH (left ventricular hypertrophy).

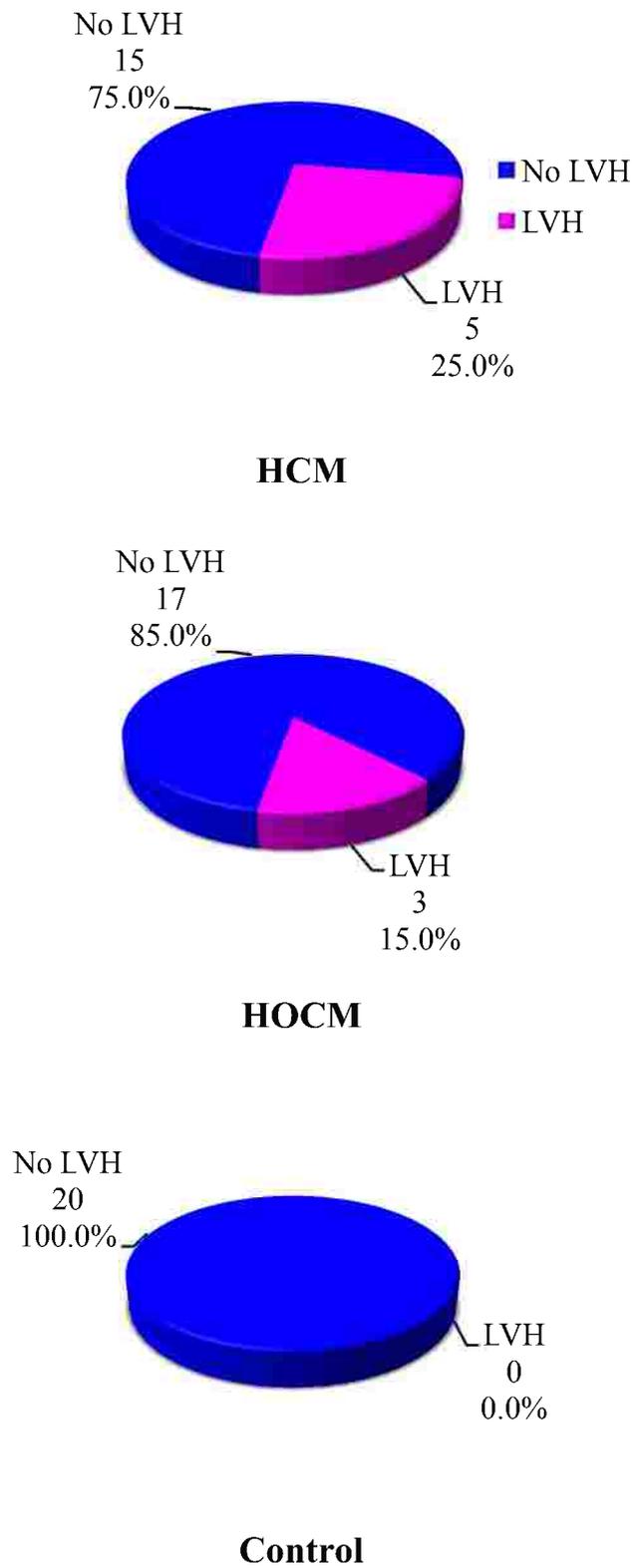


Figure (13): Comparison between the three groups according the presence of LVH.

D- Conventional transthoracic echocardiography

❖ Echocardiographic M-Mode study of the left ventricle (table 6)

The LVEDD in HCM group ranged from 2.4 to 5.9 cm with a mean (4.11 ± 1.03 cm), whereas in HOCM group the LVEDD ranged from 2.65 to 4.7 cm with a mean (3.88 ± 0.62 cm) and in the control group the LVEDD ranged from 3.0 to 5.90 cm with a mean (4.46 ± 0.68 cm), there was no significant difference between the three groups.

The LVESD in HCM group ranged from 1.60 to 3.70 cm with a mean (2.68 ± 0.77 cm) , whereas in HOCM group the LVESD ranged from 1.60 to 3.0 cm with a mean of (2.36 ± 0.45 cm) and in the control group the LVESD ranged from 2.20 to 3.20 cm with a mean of (2.64 ± 0.30 cm), there was no significant difference between the three groups.

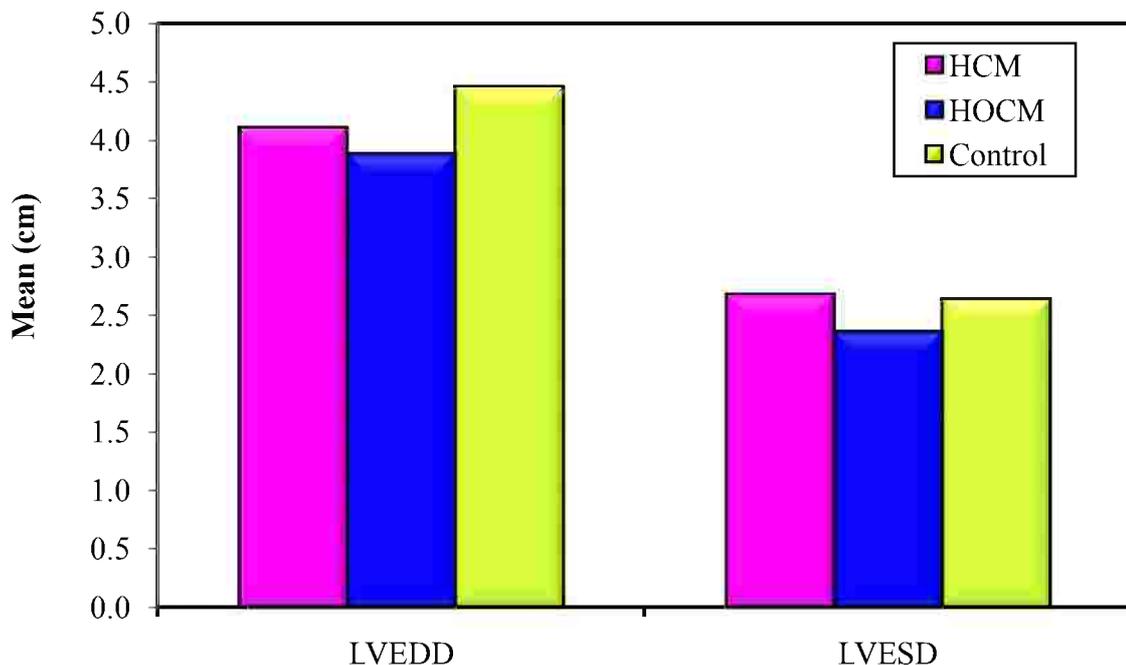


Figure (14): Comparison between the three groups according LV dimensions (LVEDD,LVESD).

The Ejection Fraction (EF) in HCM group ranged from 59.0 to 94.0% with a mean ($70.65 \pm 8.59\%$), whereas in HOCM group the EF ranged from 63.0 –to 90.0 %with a mean ($72.85 \pm 8.27\%$) and in the control group the EF ranged from 65.0 to 75.0 % with a mean ($67.80 \pm 2.95 \%$), there was no significant difference between the three groups.

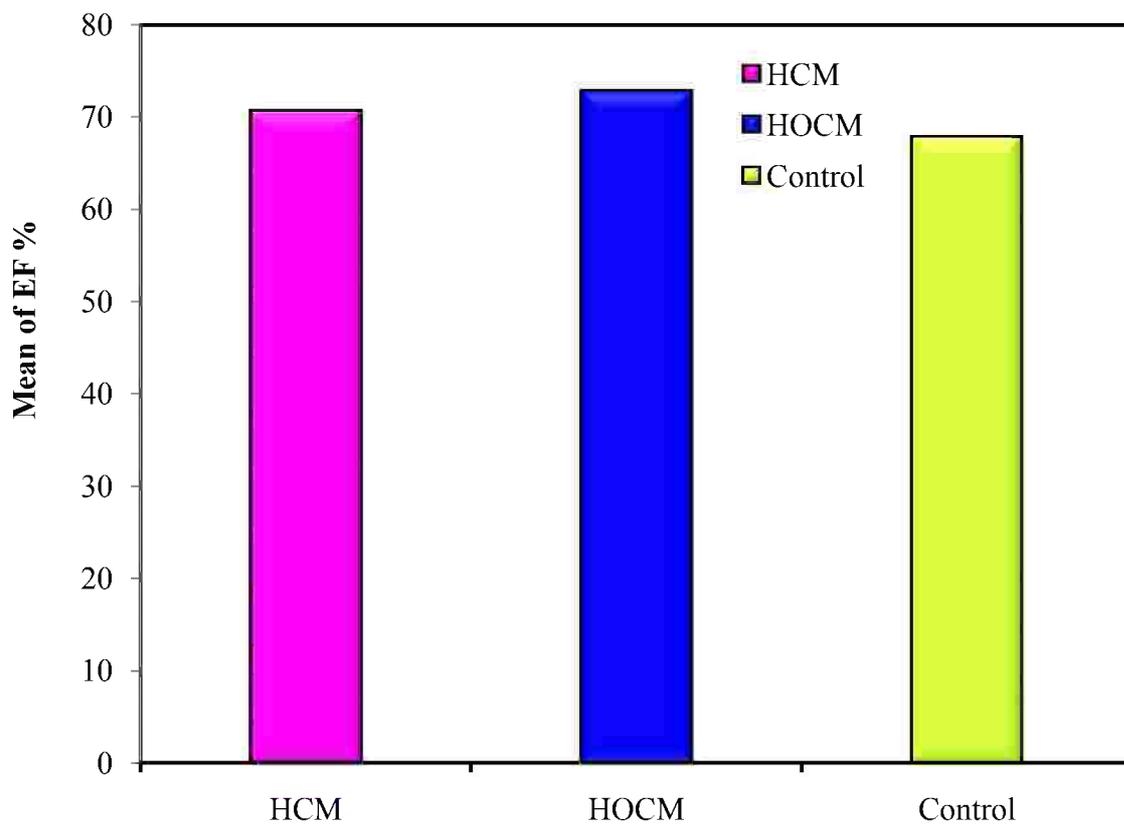


Figure (15): Comparison between the three groups according the ejection fraction.

The Interventricular septal Thickness (IVST) in HCM group ranged from 1.5 to 3.3 cm with a mean of (2.21 ± 0.57 cm) , whereas in HOCM group the IVS thickness range from 1.72 to 3.76 cm with a mean of (2.72 ± 0.61 cm) and in the control group the IVS thickness range from 0.65 to 0.90 cm with a mean of (0.78 ± 0.08 cm). It was noticed that the IVS thickness was significantly higher in the HOCM group than both the HCM group (p value =0.007) and also than the control group (p value = <0.001) , also the IVS thickness was significantly higher in the HCM group than the control group (p value = <0.001).

The Posterior Wall Thickness (PWT) in HCM group range from 0.70 to 2.50 cm with a mean of (1.28 ± 0.38 cm) , whereas in HOCM group the PWT thickness range from 0.65 to 1.70 cm with a mean of (1.28 ± 0.27) cm and in the control group the PWT thickness range from 0.60 to 0.94 cm with a mean of (0.81 ± 0.10) cm , It was noticed that there was no significant difference between the HCM and the HOCM groups but both were significantly higher than the control group ; HCM group was higher than the control group (p value = <0.001) and HOCM group was higher than the control group (p value = <0.001).

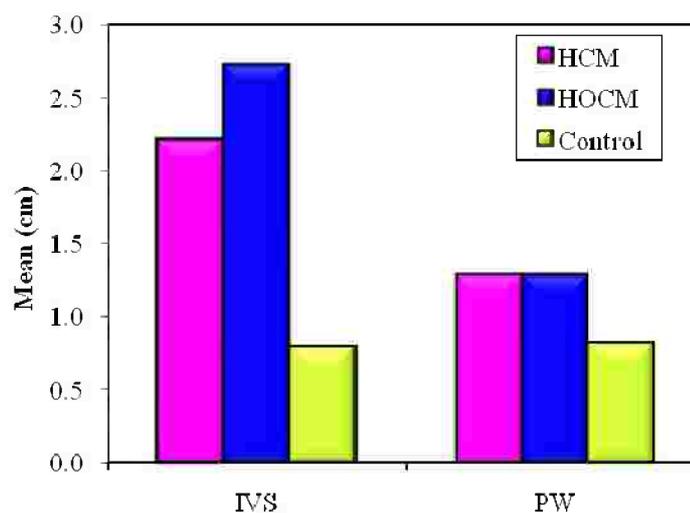


Figure (16): Comparison between the three groups according the thickness of IVS and posterior wall

The Left Ventricular Mass (LVM) in HCM group ranged from 149.37 to 668.3 gm with a mean (326.63 ± 153.32 gm) , whereas in HOCM group LVM ranged from 121.14 to 628.04 gm with a mean (373.01 ± 129.75 gm) and in the control group LVM ranged from 67.0 to 216.13 gm with a mean (118.14 ± 38.19 gm) , It was noticed that there was no significant difference between the HCM and the HOCM groups but both were significantly higher than the control group ; HCM group was higher than the control group (p value = <0.001) and HOCM group was higher than the control group (p value = <0.001).

The Left Ventricular Mass index (LVMI) in HCM group ranged from 87.07 to 365.43 gm/m^2 with a mean (176.97 ± 83.01 gm/m^2) , whereas in HOCM group LVMI ranged from 74.75 to 345.43 gm/m^2 with a mean (198.65 ± 74.15 gm/m^2) , And in the control group LVMI ranged from 44.0 to 111.20 gm/m^2 with a mean (65.05 ± 17.38 gm/m^2) It was noticed that there was no significant difference between the HCM and the HOCM groups but both were significantly higher than the control group ; HCM group was higher than the control group (p value = <0.001) and HOCM group was higher than the control group (p value = <0.001).

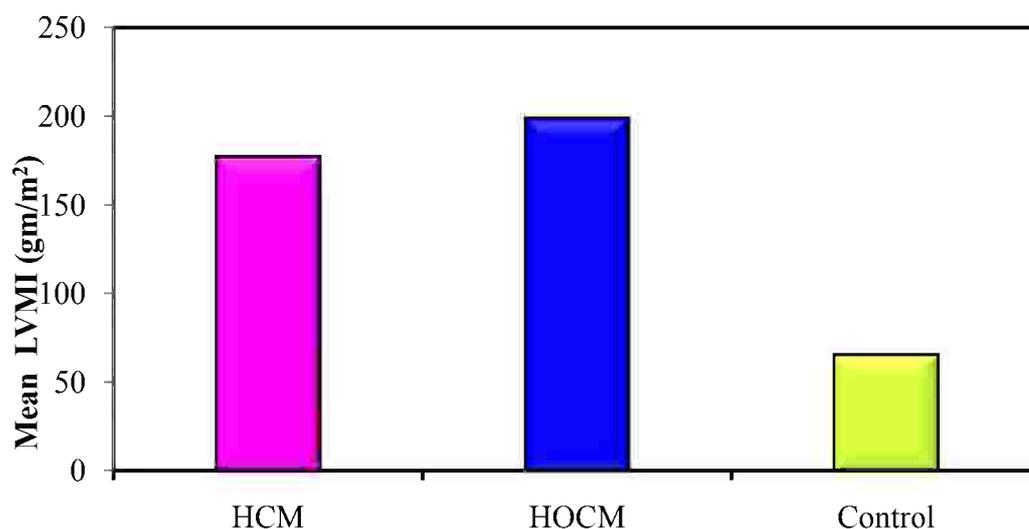


Figure (17): Comparison between the three groups according the LVMI.

Table (6): Comparison between the three studied groups according to echocardiographic M-Mode Data.

	HCM (n = 20)	HOCM (n = 20)	Control (n = 20)	Test of sig.	p
LVEDD(cm)					
Min. – Max.	2.40 – 5.90	2.65 – 4.70	3.0 – 5.90		
Mean ± SD.	4.11 ± 1.03	3.88 ± 0.62	4.46 ± 0.68	F= 2.631	0.081
Median	4.05	3.95	4.50		
Sig. bet. grps	p ₁ = 0.674, p ₂ = 0.390, p ₃ = 0.084				
LVESD(cm)					
Min. – Max.	1.60 – 3.70	1.60 – 3.0	2.20 – 3.20		
Mean ± SD.	2.68 ± 0.77	2.36 ± 0.45	2.64 ± 0.30	F= 2.028	0.141
Median	2.57	2.40	2.65		
Sig. bet. grps	p ₁ = 0.191, p ₂ = 0.974, p ₃ = 0.278				
EF(%)					
Min. – Max.	59.0 – 94.0	63.0 – 90.0	65.0 – 75.0		
Mean ± SD.	70.65 ± 8.59	72.85 ± 8.27	67.80 ± 2.95	F= 2.552	0.087
Median	70.0	74.0	67.50		
Sig. bet. grps	p ₁ = 0.620, p ₂ = 0.451, p ₃ = 0.088				
IVS(cm)					
Min. – Max.	1.50 – 3.30	1.72 – 3.76	0.65 – 0.90		
Mean ± SD.	2.21 ± 0.57	2.72 ± 0.61	0.78 ± 0.08	F= 86.436*	<0.001*
Median	2.04	2.57	0.79		
Sig. bet. grps	p ₁ = 0.007*, p ₂ <0.001*, p ₃ <0.001*				
PW(cm)					
Min. – Max.	0.70 – 2.50	0.65 – 1.70	0.60 – 0.94		
Mean ± SD.	1.28 ± 0.38	1.28 ± 0.27	0.81 ± 0.10	F= 19.351*	<0.001*
Median	1.19	1.27	0.81		
Sig. bet. grps	p ₁ = 1.000, p ₂ <0.001*, p ₃ <0.001*				
LVM(gm)					
Min. – Max.	149.37 – 668.30	121.14 – 628.04	67.0 – 216.13		
Mean ± SD.	326.63 ± 153.32	373.01 ± 129.75	118.14 ± 38.19	F= 26.654*	<0.001*
Median	282.0	370.09	117.90		
Sig. bet. grps	p ₁ = 0.467, p ₂ <0.001*, p ₃ <0.001*				
LVMl(gm/m²)					
Min. – Max.	87.07 – 365.43	74.75 – 345.43	44.0 – 111.20		
Mean ± SD.	176.97 ± 83.01	198.65 ± 74.15	65.05 ± 17.38	KW χ^2 = 37.625*	<0.001*
Median	150.70	194.34	58.97		
Sig. bet. grps	p ₁ = 0.245, p ₂ <0.001*, p ₃ <0.001*				

F: F test (ANOVA) sig. bet. Grps using Post Hoc test (Scheffe)

^{KW} χ^2 : Chi square for Kruskal Wallis test sig. bet. Gops using Mann Whitney test

p₁ : p value for comparing between HCM and HOCM

p₂ : p value for comparing between HCM and control

p₃ : p value for comparing between HOCM and control

*: Statistically significant at p ≤ 0.05

LVEDD (left ventricular end diastolic diameter) ,LVESD (left ventricular end systolic diameter),

EF (ejection fraction) , IVS (inter ventricular septum) , PW (posterior wall) ,LVM (left ventricular mass)

LVMl(left ventricular mass index).

❖ **Associated valvular disease. (Table 7)**

Mitral regurgitation was founded in 12 patients (60%) of the HCM and also the HOCM groups , in comparison to the control group 2 persons (10%) had mitral regurgitation , it was noticed that there was no significant difference between the HCM and the HOCM groups but both had significantly more mitral regurgitation than the control group ; HCM group was higher than the control group (p value = 0.001) and HOCM group was higher than the control group (p value = 0.001).

Aortic regurgitation was founded in 5 (25%) patients of the HCM group , and in 6 (30%) patients of the HOCM group whereas founded in 1 (5%) person of the control group , Aortic regurgitation was significantly higher in HOCM group than the control group (p value =0.021).

Tricusped regurgitation was founded in 3 (15%) patients of the HCM group, 1 (5%) patient of the HOCM whereas founded in 4 (20%) persons of the control ,there was significant difference between the three groups.

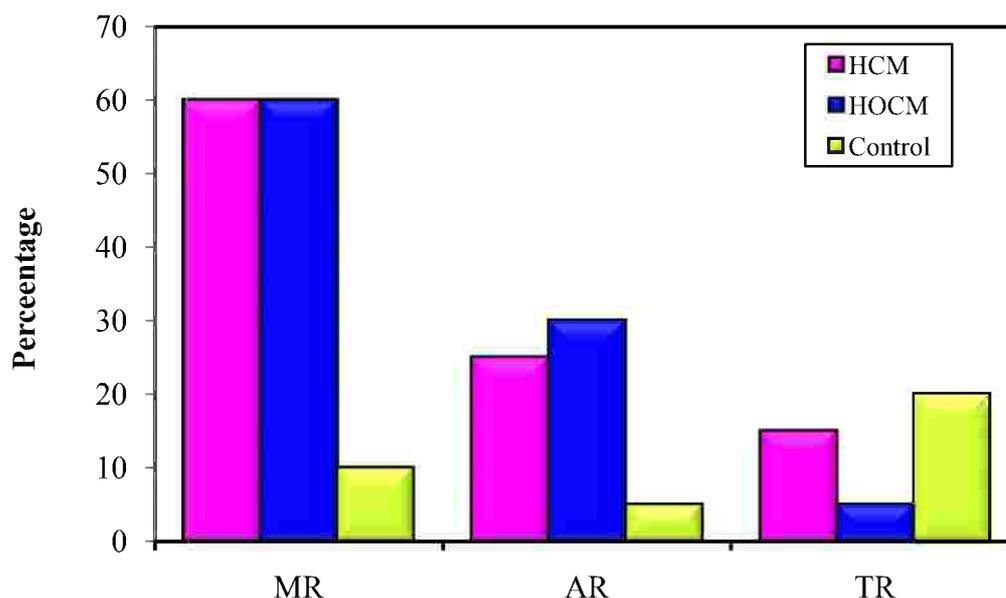


Figure (18): Associated Valvular disease

Table (7): Comparison between the three studied groups according to associated valvular lesions.

	HCM (n = 20)		HOCM (n = 20)		Control (n = 20)		χ^2	MC p
	No.	%	No.	%	No.	%		
Mitral regurgitation.								
No	8	40.0	8	40.0	18	90.0	16.411*	0.001*
Trivial	1	5.0	1	5.0	1	5.0		
Mild	11	55.0	11	55.0	1	5.0		
Sig. bet. grps	p ₁ = 1.000, p ₂ = 0.001*, p ₃ = 0.001*							
Aortic regurgitation.								
No	15	75.0	14	70.0	19	95.0	8.791*	0.028*
Trivial	2	10.0	0	0.0	1	5.0		
Mild	3	15.0	6	30.0	0	0.0		
Sig. bet. Grps	p ₁ = 0.286, p ₂ = 0.215, p ₃ = 0.021*							
Tricuspid regurgitation.								
No	17	85.0	19	95.0	16	80.0	3.793	0.481
Trivial	1	5.0	0	0.0	3	15.0		
Mild	2	10.0	1	5.0	1	5.0		
Sig. bet. grps	p ₁ = 0.606, p ₂ = 0.694, p ₃ = 0.229							

χ^2 : Value for chi square

MC: Monte Carlo test

p₁ : p value for chi square test for comparing between HCM and HOCM

p₂ : p value for chi square test for comparing between HCM and control

p₃ : p value for chi square test for comparing between HOCM and control

*: Statistically significant at p ≤ 0.05

❖ **LVOT Gradient (table 8)**

In HCM group the LVOT gradient at rest ranged from 5.20 to 19.30 mmHg with a mean of $(9.95 \pm 4.48 \text{ mmHg})$ increased with provocation with valsalva to a range 8.0 to 23.0mmHg with a mean $(15.57 \pm 4.80 \text{ mmHg})$, whereas in HOCM group the LVOT gradient at rest ranged from 10.0 to 65.0 mmHg with a mean of $(34.65 \pm 17.34 \text{ mmHg})$ increased with provocation with valsalva to a range 32 to 97 mmHg with a mean $(61.24 \pm 17.87\text{mmHg})$ in comparison to the control group the LVOT gradient at rest ranged from 2 to 5 mmHg with a mean of $(2.90 \pm 1.17 \text{ mmHg})$ increased with provocation with valsalva to a range 3 to 8 mHg with a mean $(5.30 \pm 1.69 \text{ mmHg})$.

The HOCM group had significantly higher LVOT rest gradient than HCM group (p value <0.001) and than the control group (p value <0.001)

And by provocation the HOCM group had significantly higher gradient than HCM group (p value <0.001) and than the control group (p value <0.001) , also HCM group had significantly higher gradient than the control group (p value =0.014).

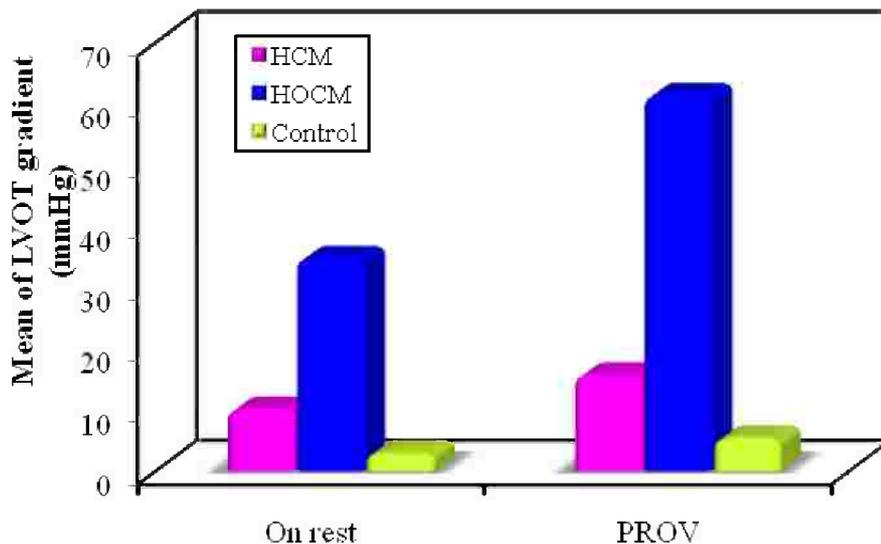


Figure (19): Comparison between the three groups according the LVOT gradient during rest and with provocation

Table (8): Comparison between the three studied groups according to LVOT gradient.

	HCM (n = 20)	HOCM (n = 20)	Control (n = 20)	F	p
On rest					
Min. – Max.	5.20 – 19.30	10.0 – 65.0	2.0 – 5.0		
Mean ± SD.	9.95 ± 4.48	34.65 ± 17.34	2.90 ± 1.17	51.786*	<0.001*
Median	8.25	34.0	2.0		
Sig. bet. grps	p ₁ <0.001*, p ₂ = 0.108, p ₃ <0.001*				
PROV					
Min. – Max.	8.0 – 23.0	32.0 – 97.0	3.0 – 8.0		
Mean ± SD.	15.57 ± 4.80	61.24 ± 17.87	5.30 ± 1.69	154.068*	<0.001*
Median	15.0	61.50	5.0		
Sig. bet. grps	p ₁ <0.001*, p ₂ = 0.014*, p ₃ <0.001*				

F: F test (ANOVA)

p₁ : p value for Post Hoc test (Scheffe) for comparing between HCM and HOCM

p₂ : p value for Post Hoc test (Scheffe) for comparing between HCM and control

p₃ : p value for Post Hoc test (Scheffe) for comparing between HOCM and control

*: Statistically significant at p ≤ 0.05

LVOT (left ventricular out flow tract) , PROV (provocation)

❖ Echocardiographic study of the left atrium (table 9)

The anteroposterior diameter (AP-D) of the left atrium in HCM group ranged from 3.0 to 5.8 cm with a mean (4.36 ± 0.83 cm) , whereas in HOCM group ranged from 2.80 to 5.30 cm with a mean (4.10 ± 0.6 cm) and in the control group AP-D ranged from 2.80 to 3.90 cm with a mean (3.28 ± 0.31 cm) , there was no significant difference between the HCM and the HOCM group but both are significantly higher than the control group (p values < 0.001).

The superior – inferior diameter (SI-D) of the left atrium in HCM group ranged from 3.60 to 7.0 cm with a mean (6.03 ± 0.88 cm) , whereas in HOCM group ranged from 4.41 to 6.9 cm with a mean (5.34 ± 0.65 cm) and in the control group SI-D ranged from 3.70 to 4.60 cm with a mean (4.25 ± 0.29 cm) , the SI-D in HCM group significantly higher than both the HOCM group (p value =0.008) and than the control group (p value < 0.001) , also it is significantly higher in HOCM group than the control group (p value =0.002).

The mediolateral diameter (ML-D) of the left atrium in HCM group ranged from 3.30 to 5.80 cm with a mean (4.77 ± 0.69 cm) , whereas in HOCM group ranged from 3.50 to 5.20 cm with a mean (4.31 ± 0.51 cm) and in the control group ML-D ranged from 3.20 to 4.20 cm with a mean (3.65 ± 0.33 cm) , the ML-D in HCM group significantly higher than both the HOCM group (p value =0.028) and than the control group (p value < 0.001) , also it is significantly higher in HOCM group than the control group (p value =0.001).

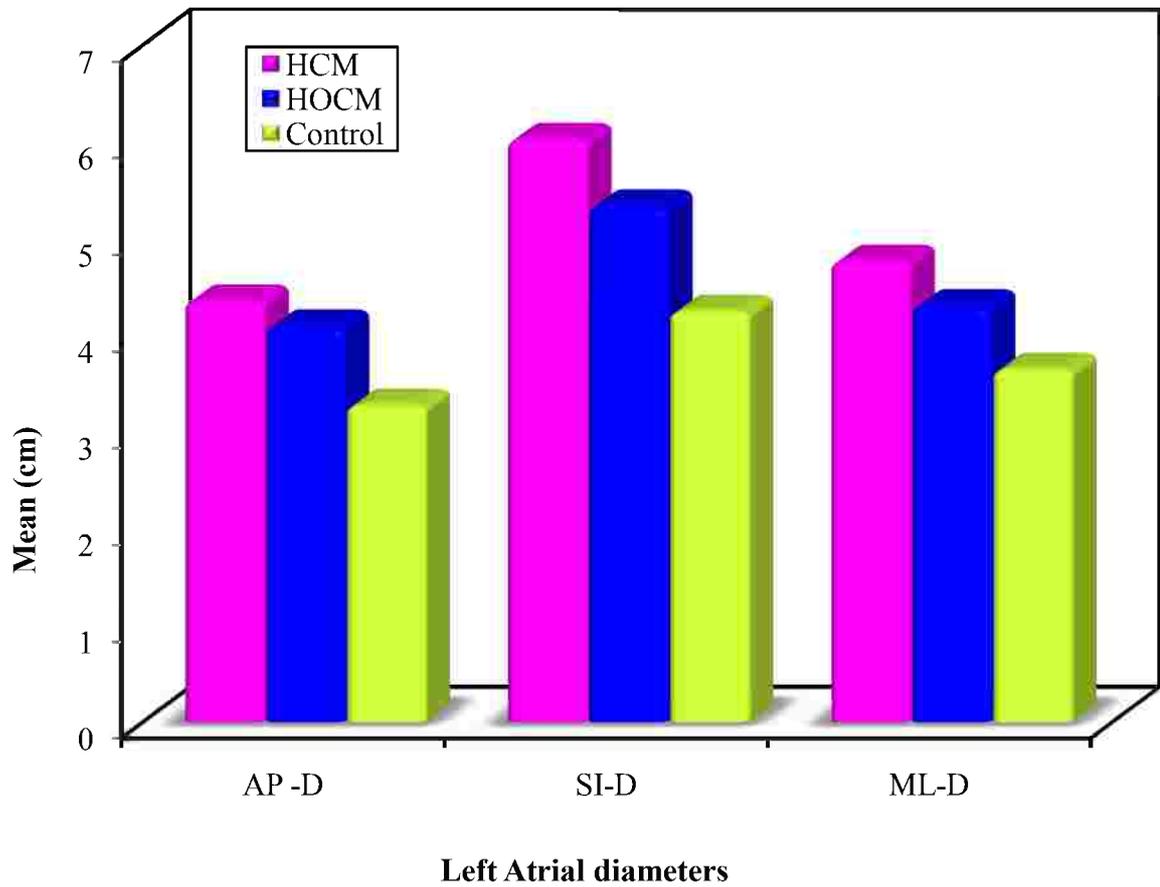


Figure (20): Comparison between the three groups as regard LA diameters.

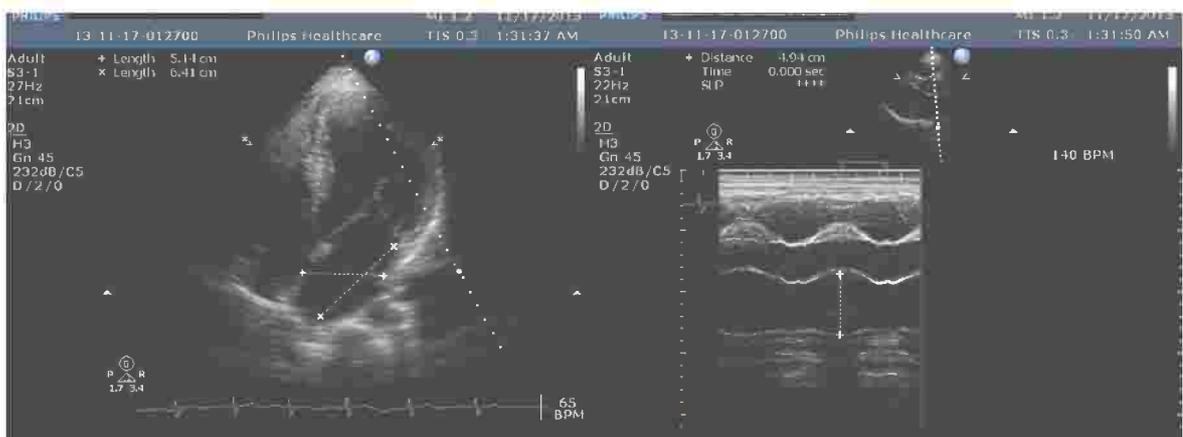


Figure (21): LA diameters in patients with non obstructive HCM.

The left atrial maximum volume (LA max. volume) in HCM group ranged from 38.0 to 94.40 ml with a mean (72.98 ± 15.87 ml) , whereas in HOCM group ranged from 46.0 to 88.10 ml with a mean (59.66 ± 12.62 ml) and in the control group, LA max. Volume ranged from 30.0 to 49.0 ml with a mean (43.15 ± 4.79 ml), it was noticed that HCM group had significantly higher LA max. Volume than both the HCM group (p value =0.004) and the control group (p value <0.001) . Also the HOCM group had LA max. Volume significantly higher than the control (p value <0.001).

The left atrial minimum volume in HCM group ranged from 17.60 to 58.0 ml with a mean (40.01 ± 14.52 ml), whereas in HOCM group ranged from 14.70 to 54.0 ml with a mean (31.49 ± 11.37 ml) and in the control group LA minimum volume ranged from 16.0 to 20.0ml with a mean (17.75 ± 1.25 ml) , it was noticed that HCM group had significantly higher LA minimum volume than both the HCM group (p value =0.049) and the control group (p value <0.001) , also the HOCM group had LA minimum volume significantly higher than the control (p value =0.001).

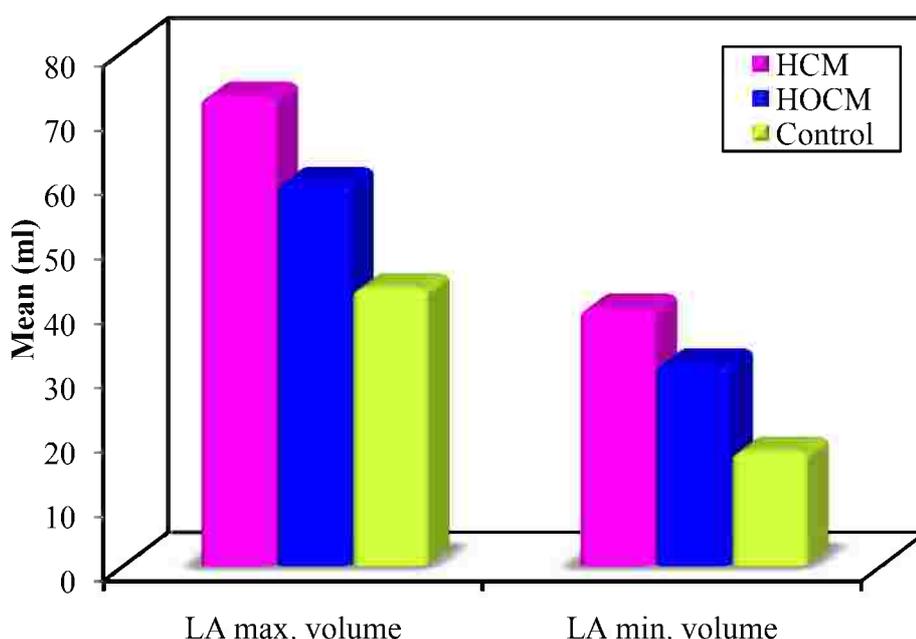


Figure (22): Comparison between the three groups as regard LA maximum volume and LA minimum volume



Figure (23): LA minimum and maximum volumes in patient with HOCM.

The left atrial volume index in HCM group ranged from 19.38 to 50.28 ml/m² with a mean (39.75 ± 8.44 ml/m²), whereas in HOCM group ranged from 22.18 to 50.92 ml/m² with a mean (30.96 ± 8.03 ml/m²) and in the control group LA volume index ranged from 19.86 to 27.56 ml/m² with a mean of (23.78 ± 1.96 ml/m²), it was noticed that HCM group had significantly higher LA volume index than both the HCM group (p value =0.002) and the control group (p value <0.001). Also the HOCM group had LA volume index significantly higher than the control (p value =0.001).

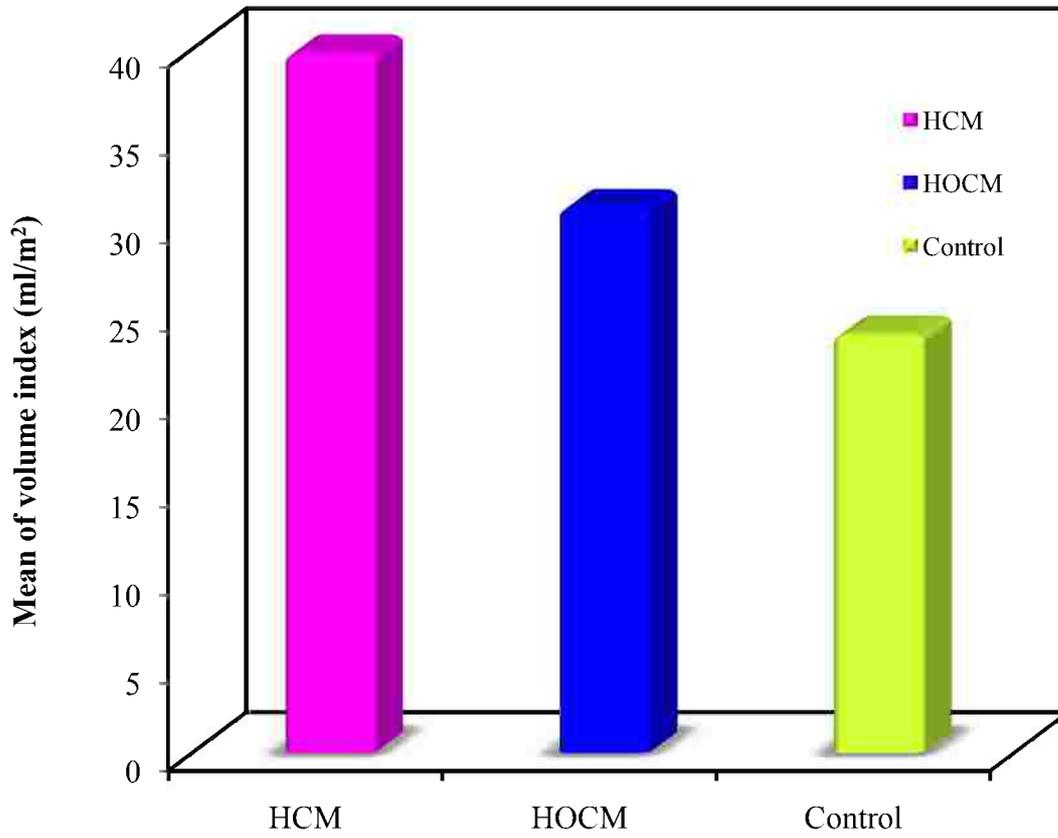


Figure (24): Comparison between the three groups according the LA volume index.

Table (9): Echocardiographic Study of The Left Atrial diameters and volumes.

	HCM (n = 20)	HOCM (n = 20)	Control (n = 20)	Test of sig.	p
AP -D (cm)					
Min. – Max.	3.0 – 5.80	2.80 – 5.30	2.80 – 3.90		
Mean ± SD.	4.36 ± 0.83	4.10 ± 0.60	3.28 ± 0.31	F= 16.545*	<0.001*
Median	4.50	4.20	3.30		
Sig. bet. grps	p ₁ = 0.429, p ₂ <0.001*, p ₃ <0.001*				
SI-D (cm)					
Min. – Max.	3.60 – 7.0	4.41 – 6.90	3.70 – 4.60		
Mean ± SD.	6.03 ± 0.88	5.34 ± 0.65	4.25 ± 0.29	F= 37.885*	<0.001*
Median	5.95	5.30	4.25		
Sig. bet. grps	p ₁ = 0.006*, p ₂ <0.001*, p ₃ <0.001*				
ML-D (cm)					
Min. – Max.	3.30 – 5.80	3.50 – 5.20	3.20 – 4.20		
Mean ± SD.	4.77 ± 0.69	4.31 ± 0.51	3.65 ± 0.33	F= 22.528*	<0.001*
Median	5.0	4.15	3.75		
Sig. bet. grps	p ₁ = 0.028*, p ₂ <0.001*, p ₃ = 0.001*				
LA max. volume(ml)					
Min. – Max.	38.0 – 94.40	46.0 – 88.10	30.0 – 49.0		
Mean ± SD.	72.98 ± 15.87	59.66 ± 12.62	43.15 ± 4.79	F= 30.858*	<0.001*
Median	78.70	60.0	44.0		
Sig. bet. grps	p ₁ = 0.004*, p ₂ <0.001*, p ₃ <0.001*				
LA min. volume(ml)					
Min. – Max.	17.60 – 58.0	14.70 – 54.0	16.0 – 20.0		
Mean ± SD.	40.01 ± 14.52	31.49 ± 11.37	17.75 ± 1.25	F= 22.142*	<0.001*
Median	44.25	30.85	17.50		
Sig. bet. grps	p ₁ = 0.049*, p ₂ <0.001*, p ₃ = 0.001*				
Volume index(ml/m²)					
Min. – Max.	19.38 – 50.28	22.18 – 50.92	19.86 – 27.56		
Mean ± SD.	39.75 ± 8.44	30.96 ± 8.03	23.78 ± 1.96	^{KW} χ ² =29.038*	<0.001*
Median	42.14	29.59	24.12		
Sig. bet. grps	p ₁ = 0.002*, p ₂ <0.001*, p ₃ = 0.001*				

F: F test (ANOVA) sig. bet. Grps using Post Hoc test (Scheffe)

^{KW}χ²: Chi square for Kruskal Wallis test sig. bet. Gops using Mann Whitney test

p₁ : p value for comparing between HCM and HOCM

p₂ : p value for comparing between HCM and control

p₃ : p value for comparing between HOCM and control

*: Statistically significant at p ≤ 0.05

❖ **Trans-mitral flow velocities table (10)**

Early trans-mitral flow velocity (E wave) in HCM group ranged from 38 to 117 cm/sec with a mean of $(69.3 \pm 20.9 \text{ cm/sec})$, whereas in HOCCM group ranged from 46 to 97 cm/sec with a mean of $(69.9 \pm 15.7 \text{ cm/sec})$ and in the control group the E wave velocity ranged from 50 to 91 cm/sec with a mean of $(69.1 \pm 12.1 \text{ cm/sec})$, there was no significant difference between the three groups.

Atrial trans-mitral flow velocity (A wave) in HCM group ranged from 11.9 to 93 cm/sec with a mean of $(43.8 \pm 19.8 \text{ cm/sec})$ whereas in HOCCM group ranged from 24 to 82 cm/sec with a mean of $(50.8 \pm 17.5 \text{ cm/sec})$ and in the control group the A wave velocity ranged from 30 to 76 cm/sec with a mean of $(53.6 \pm 11.9 \text{ cm/sec})$, there was no significant difference between the three groups.

Ratio of Early trans-mitral flow velocity to Atrial trans-mitral flow velocity (E/A) in HCM group ranged from 0.78 to 5.55 with a mean of (1.97 ± 1.31) , whereas in HOCCM group ranged from 0.76 to 3.20 with a mean of (1.51 ± 0.58) and in the control group the E/A ratio ranged from 1.11 to 1.80 with a mean of (1.32 ± 0.19) , there was no significant difference between the three groups.

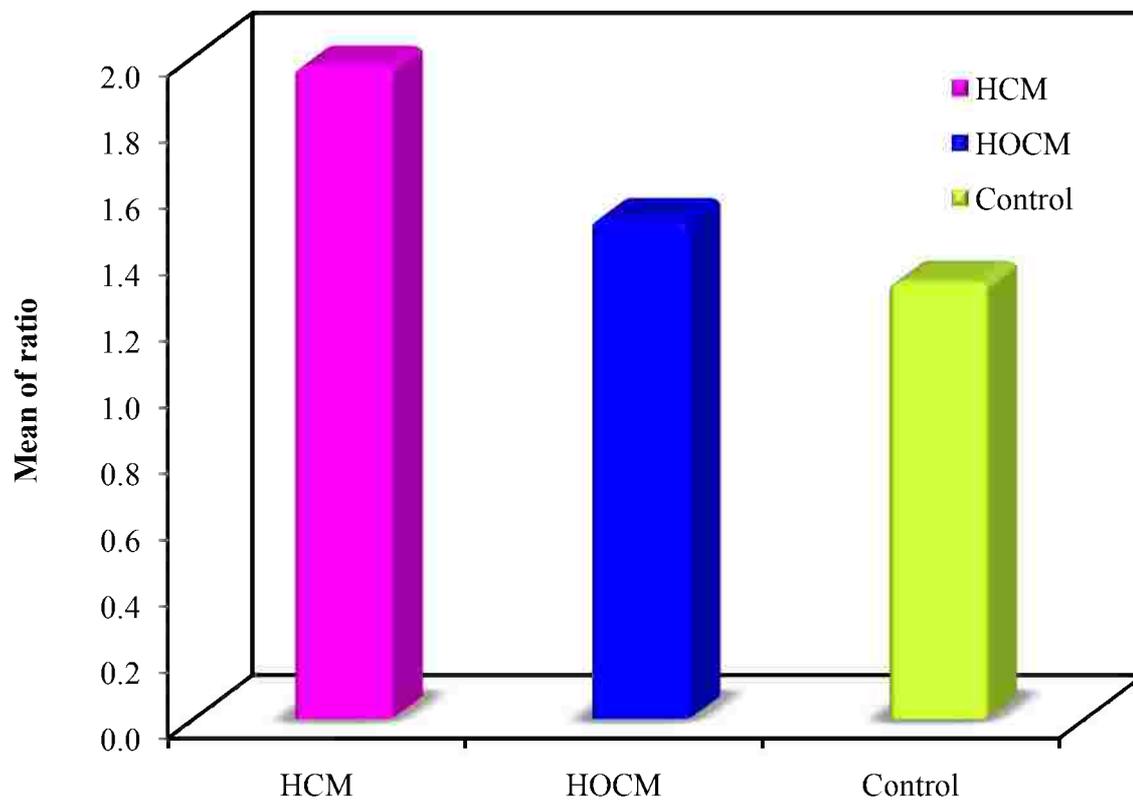


Figure (25): Comparison between the three groups as regard E/A ratio

Table (10): Comparison between the three studied groups according to mitral diastolic flow.

Mitral flow	HCM (n = 20)	HOCM (n = 20)	Control (n = 20)	Test of sig.	p
E-wave (cm/sec)					
Min. – Max.	38.0 – 117.0	46.0 – 97.0	50.0 – 91.0		
Mean ± SD.	69.3 ± 20.9	69.9 ± 15.7	69.1 ± 12.1	F= 0.012	0.988
Median	65.5	70	71.0		
Sig. bet. grps	p ₁ = 0.995, p ₂ = 0.999, p ₃ = 0.988				
A-wave (cm/sec)					
Min. – Max.	11.9 – 93.0	24.0 – 82.0	30.0 – 76.0		
Mean ± SD.	43.8 ± 19.8	50.8 ± 17.5	53.6 ± 11.9	F= 1.808	0.173
Median	40.0	45.5	56.5		
Sig. bet. grps	p ₁ = 0.423, p ₂ = 0.191, p ₃ = 0.872				
E/A ratio					
Min. – Max.	0.78 – 5.55	0.76 – 3.20	1.11 – 1.80		
Mean ± SD.	1.97 ± 1.31	1.51 ± 0.58	1.32 ± 0.19	^{KW} χ ² =1.709	0.425
Median	1.53	1.32	1.30		
Sig. bet. grps	p ₁ = 0.433, p ₂ = 0.185, p ₃ = 0.675				

F: F test (ANOVA) sig. bet. Grps using Post Hoc test (Scheffe)

^{KW}χ²: Chi square for Kruskal Wallis test sig. bet. Gops using Mann Whitney test

p₁ : p value for comparing between HCM and HOCM

p₂ : p value for comparing between HCM and control

p₃ : p value for comparing between HOCM and control

E (early trans-mitral flow velocity) , A (atrial trans-mitral flow velocity).

❖ Mitral annulus tissue Doppler parameters (table 11)

Peak ventricular systolic velocity of mitral annulus tissue (s') in HCM group ranged from 5.0 to 11.40 cm/sec with a mean of $(7.92 \pm 1.81 \text{ cm/sec})$, whereas in HOCM group ranged from 4.20 to 19.70 cm/sec with a mean of $(8.31 \pm 3.10 \text{ cm/sec})$ and in the control group s' ranged from 6.70 to 12.10 cm/sec with a mean of $(9.02 \pm 1.66 \text{ cm/sec})$, there was no significant difference between the three groups.

Peak early ventricular diastolic velocity of mitral annulus tissue (e') in HCM group ranged from 5.90 to 17.80 cm/sec with a mean of $(8.60 \pm 2.97 \text{ cm/sec})$, whereas in HOCM group ranged from 4.0 to 16.60 cm/sec with a mean of $(8.11 \pm 2.79 \text{ cm/sec})$ and in the control group, e' ranged from 7.90 to 15.90 cm/sec with a mean of $(11.06 \pm 2.16 \text{ cm/sec})$, there was no significant difference between HCM and HOCM but both had significantly lower e' than the control group (p values =0.001, < 0.001 in order)

The Mitral annulus tissue doppler during atrial contraction (a') in HCM range from 3.40 to 16.40 cm/sec with a mean of $(8.68 \pm 3.78 \text{ cm/sec})$, whereas in HOCM ranged from 2.0 to 19.60 cm/sec with a mean of $(8.13 \pm 4.45 \text{ cm/sec})$ and in the control group, a' had range from 5.60 to 13.0 cm/sec with a mean of $(8.75 \pm 1.97 \text{ cm/sec})$, there was no significant difference between the three groups.

The e/e' ratio in HCM group ranged from 0.35 to 1.57 with a mean (0.87 ± 0.34) , whereas in HOCM group ranged from 0.37 to 1.88 with a mean (0.96 ± 0.42) and in the control group the e/e' ratio ranged from 0.46 to 0.93 with a mean (0.63 ± 0.15) , there was no significant difference between HCM and HOCM but both had significantly higher e/e' ratio than the control group (p values =0.007, = 0.002 in order).

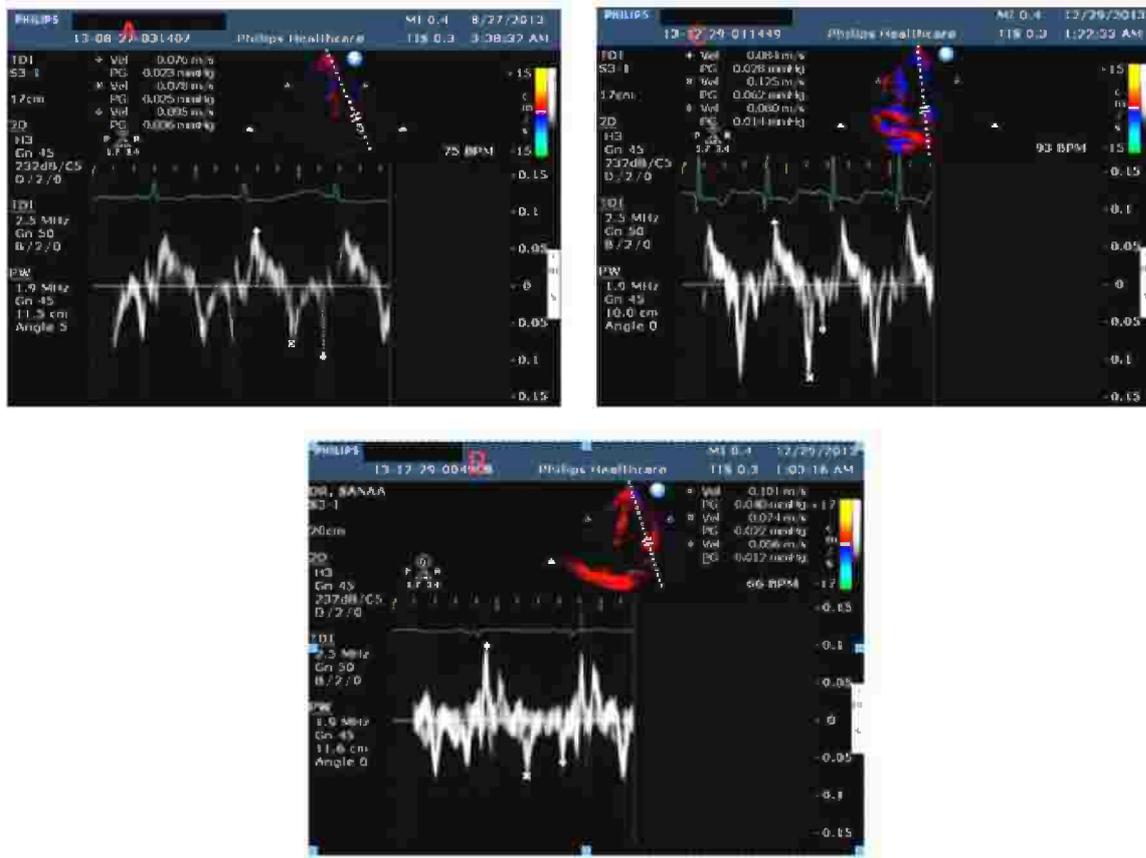


Figure (26): The Mitral annulus tissue Doppler in a patient with HCM (A), patient with HOCM (B) and in healthy subject (C)

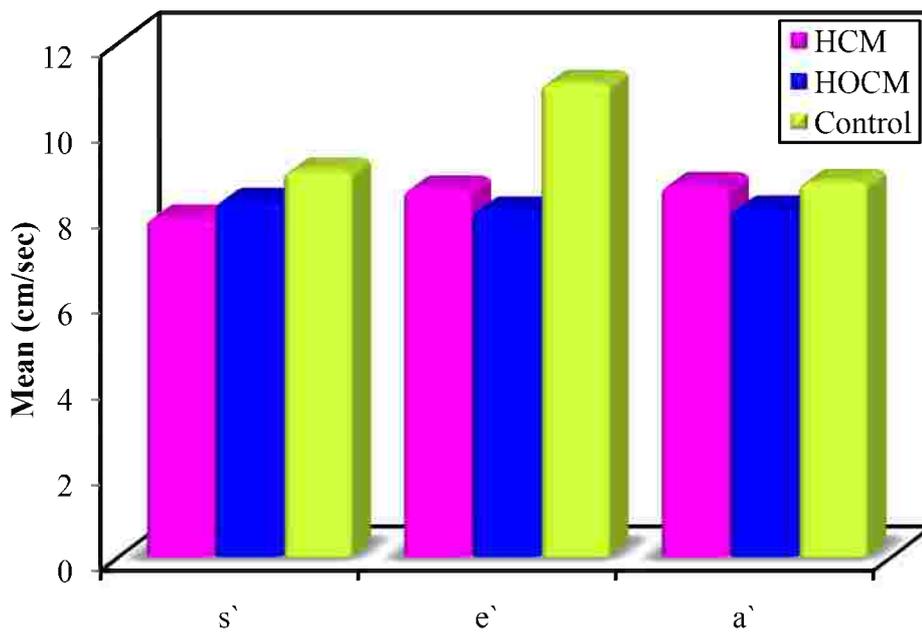


Figure (27): Mitral Annulus tissue doppler

Table (11): Comparison between the three studied groups according to TDI at the mitral annulus.

TDI mit	HCM (n = 20)	HOCM (n = 20)	Control (n = 20)	KW χ^2	P
s`-wave					
Min. – Max.	5.0 – 11.40	4.20 – 19.70	6.70 – 12.10		
Mean \pm SD.	7.92 \pm 1.81	8.31 \pm 3.10	9.02 \pm 1.66	4.119	0.128
Median	7.90	7.85	8.50		
Sig. bet. grps	$p_1= 0.914, p_2= 0.067, p_3= 0.069$				
e`-wave					
Min. – Max.	5.90 – 17.80	4.0 – 16.60	7.90 – 15.90		
Mean \pm SD.	8.60 \pm 2.97	8.11 \pm 2.79	11.06 \pm 2.16	15.150*	0.001*
Median	8.0	8.0	11.0		
Sig. bet. grps	$p_1= 0.765, p_2= 0.001^*, p_3<0.001^*$				
a`-wave					
Min. – Max.	3.40 – 16.40	2.0 – 19.60	5.60 – 13.0		
Mean \pm SD.	8.68 \pm 3.78	8.13 \pm 4.45	8.75 \pm 1.97	1.619	0.445
Median	8.45	7.20	8.75		
Sig. bet. grps	$p_1= 0.542, p_2= 0.839, p_3= 0.144$				
e/e` ratio					
Min. – Max.	0.35 – 1.57	0.37 – 1.88	0.46 – 0.93		
Mean \pm SD.	0.87 \pm 0.34	0.96 \pm 0.42	0.63 \pm 0.15	11.510*	0.003*
Median	0.87	0.88	0.57		
Sig. bet. grps	$p_1= 0.534, p_2= 0.007^*, p_3= 0.002^*$				

s` (peak ventricular systolic velocity of mitral annulus tissue), e` (peak early ventricular diastolic velocity of mitral annulus tissue), a` (mitral annulus tissue doppler during atrial contraction)

KW χ^2 : Chi square for Kruskal Wallis test

p₁ : p value for Mann Whitney test for comparing between HCM and HOCM

p₂ : p value for Mann Whitney test for comparing between HCM and control

p₃ : p value for Mann Whitney test for comparing between HOCM and control

*: Statistically significant at p \leq 0.05

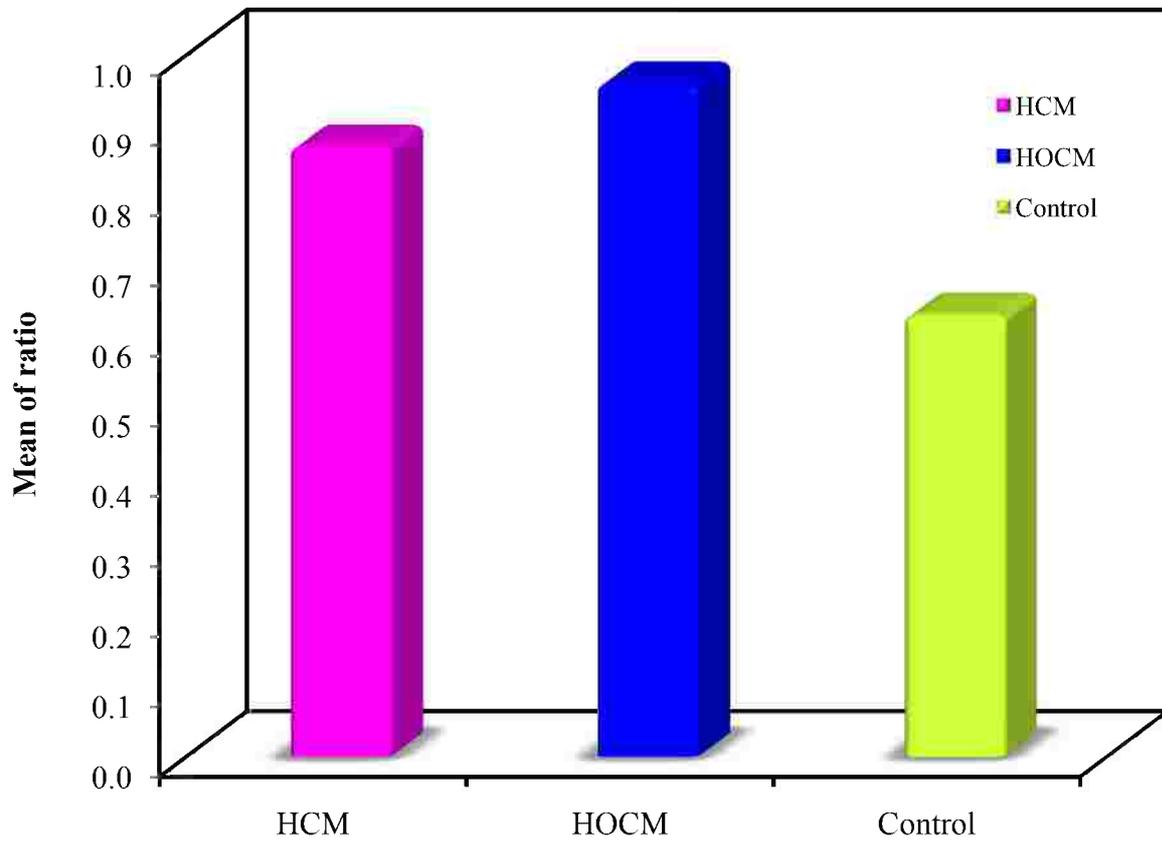


Figure (28): Comparison between the three groups as regard e/e' ratio

E- left atrium deformation study by tissue Doppler

- Strain and Strain rate study of the left atrial lateral wall (Table 12)

Strain of the left atrial lateral wall (S) in HCM group ranged from 29.4 to 46 % with a mean of $(38.5 \pm 4.01\%)$, whereas in HOCM group ranged from 26.20 to 43.0% with a mean of $(33.03 \pm 3.80\%)$ and in the control group S ranged from 36.70 to 55.0% with a mean of $(45.48 \pm 4.57\%)$.

Both HCM and HOCM groups had significantly lower S than the control group (p values <0.001) , also HOCM group had significantly lower S than HCM group (p value < 0.001).

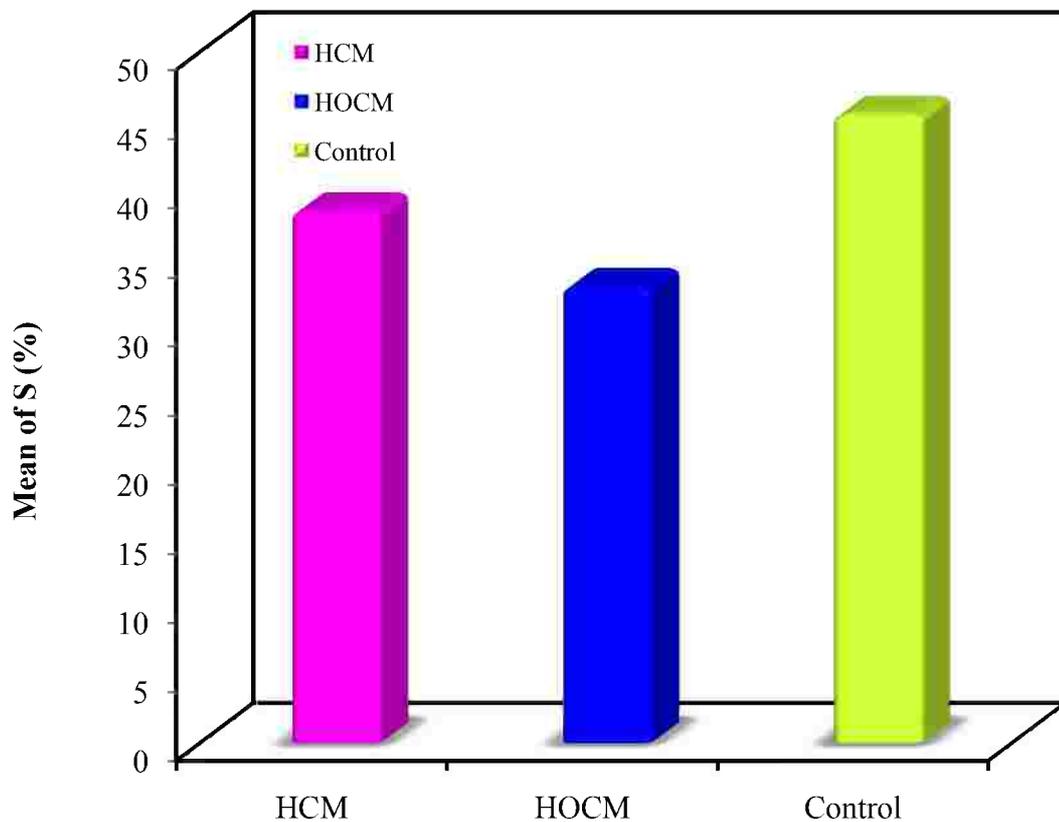


Figure (29): Comparison between the three groups according Left atrial lateral wall strain

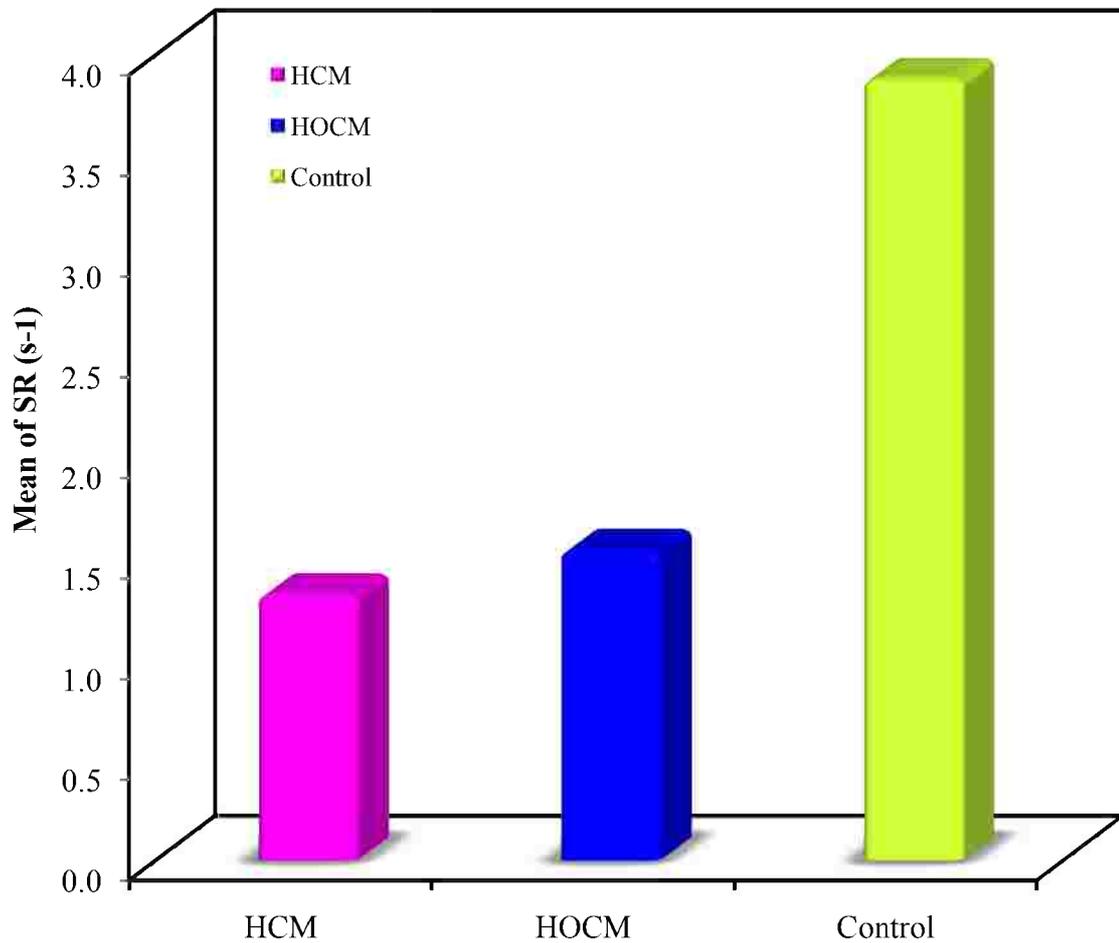


Figure (31): Comparison between the three groups according Left atrial lateral wall strain rate

Time to S in HCM ranged from 195.0 to 640 msec with a mean (384.40 ± 108.61 msec) , whereas in HOCM group ranged from 132.0 to 560 msec with a mean (364.30 ± 129.84 msec) and in the control group time to S ranged from 407.0 to 540.0 msec with a mean (468.55 ± 37.98 msec). Both HCM and HOCM groups had significantly lower time to S than the control group (p values 0.036 and 0.007 in order), but no significant difference between HOCM and HOCM groups.

Time to SR in HCM group ranged from 117 to 309 msec with a mean (218.70 ± 46.64 msec), whereas in HOCM group ranged from 129 to 299 msec with a mean (204.05 ± 52.48 msec) and in the control group time to SR ranged from 200.0 to 370.0 msec with a mean (256.90 ± 43.51 msec). Both HCM and HOCM groups had significantly lower time to S than the control group (p values 0.042 and 0.003 in order), but no significant difference between HOCM and HOCM groups.

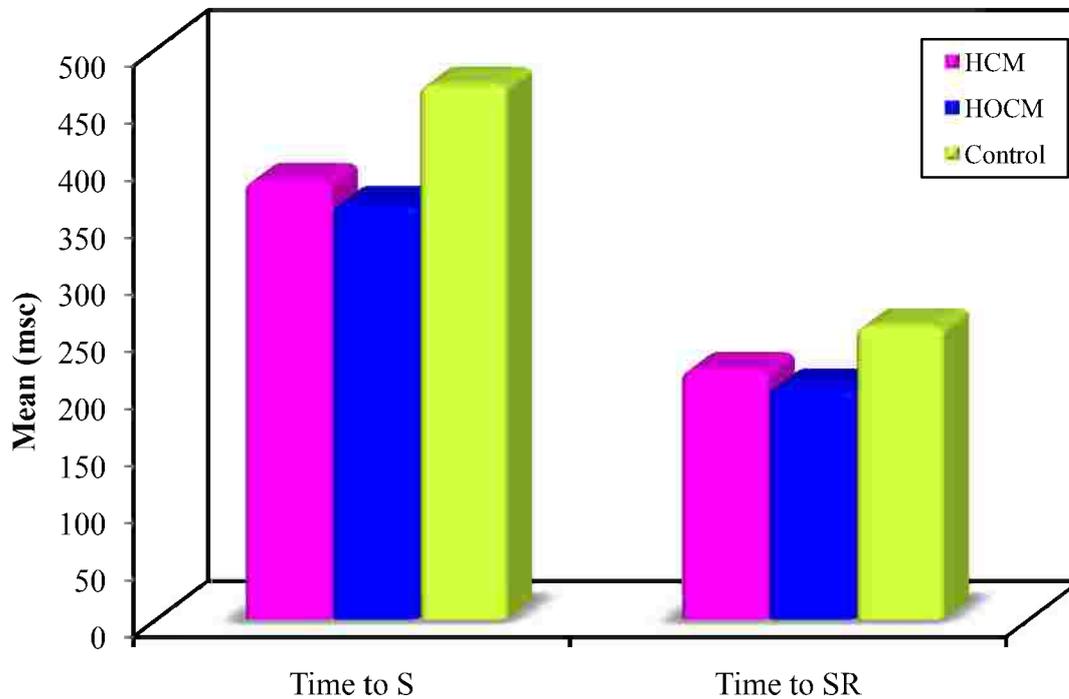


Figure (32): Comparison between the three groups according to time to strain and time to strain rate.

Table (12): Comparison between the three studied groups according to strain profile in lateral left atrial wall.

Strain profile	HCM (n = 20)	HOCM (n = 20)	Control (n = 20)	$^{KW}\chi^2$	P
S (%)					
Min. – Max.	29.40 – 46.0	26.20 – 43.0	36.70 – 55.0	$^{KW}\chi^2=36.209^*$	<0.001*
Mean ± SD.	38.50 ± 4.01	33.03 ± 3.80	45.48 ± 4.57		
Median	38.80	32.0	47.50		
Sig. bet. grps	$p_1 < 0.001^*$, $p_2 < 0.001^*$, $p_3 < 0.001^*$				
SR (s⁻¹)					
Min. – Max.	0.90 – 1.90	1.10 – 2.50	2.60 – 5.0	$^{KW}\chi^2=40.419^*$	<0.001*
Mean ± SD.	1.32 ± 0.27	1.54 ± 0.45	3.88 ± 0.68		
Median	1.29	1.45	4.10		
Sig. bet. grps	$p_1 = 0.146$, $p_2 < 0.001^*$, $p_3 < 0.001^*$				
Time to S. (msec)					
Min. – Max.	195.0 – 640.0	132.0 – 560.0	407.0 – 540.0	F= 6.098*	0.004*
Mean ± SD.	384.40 ± 108.61	364.30 ± 129.84	468.55 ± 37.98		
Median	377.0	397.50	470.0		
Sig. bet. Grps	$p_1 = 0.818$, $p_2 = 0.036^*$, $p_3 = 0.007^*$				
Time to SR.(msec)					
Min. – Max.	117.0 – 309.0	129.0 – 299.0	200.0 – 370.0	F= 6.817*	0.002*
Mean ± SD.	218.70 ± 46.64	204.05 – 52.48	256.90 ± 43.51		
Median	208.0	200.0	260.0		
Sig. bet. grps	$p_1 = 0.614$, $p_2 = 0.042^*$, $p_3 = 0.003^*$				

S(stain) , SR (strain rate) ,Time to S (time to strain) , Time to SR (time to strain rate).

F: F test (ANOVA) sig. bet. Grps using Post Hoc test (Scheffe)

$^{KW}\chi^2$: Chi square for Kruskal Wallis test sig. bet. Gops using Mann Whitney test

p_1 : p value for comparing between HCM and HOCM

p_2 : p value for comparing between HCM and control

p_3 : p value for comparing between HOCM and control

*: Statistically insignificant at $p > 0.05$

*: Statistically significant at $p \leq 0.05$

• **LA regional velocities in the anterior wall table (13)**

Velocities in mid segment of the anterior wall of the left atrium:

- **S`wave** in HCM ranged from 1.40 to 3.99 cm/sec with a mean (2.34 ± 0.74 cm/sec) vs 1.87 to 6.21 cm/sec with a mean (2.97 ± 1.19 cm/sec) in HOCM and 3.10 to 5.40 cm/sec with a mean (4.60 ± 0.63 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001), but no significant difference between HCM and HOCM groups.
- **è wave** in HCM ranged from 1.43 to 3.78 cm/sec with a mean (2.34 ± 0.64 cm/sec) vs 1.29 - 6.01 cm/sec with a mean (2.88 ± 1.34 cm/sec) in HOCM and 3.0 - 6.40 cm/sec with a mean (5.0 ± 0.91 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001), but no significant difference between HCM and HOCM groups.
- **à wave** in HCM ranged from 1.47 to 3.66 cm/sec with a mean (2.33 ± 0.65 cm/sec) vs 1.87 - 5.87 cm/sec with a mean (3.04 ± 1.06 cm/sec) in HOCM and 3.20 - 5.40 cm/sec with a mean (4.66 ± 0.60 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001), also it is higher significantly in HOCM group than in the HCM group (p value 0.042).

Velocities in superior segment of the anterior wall of the left atrium:

- **S` wave** in HCM ranged from 1.39 to 3.33 cm/sec with a mean (2.01 ± 0.54 cm/sec) vs 1.37 - 6.17 cm/sec with a mean (2.42 ± 1.13 cm/sec) in HOCCM and 3.0 - 5.50 cm/sec with a mean (4.45 ± 0.72 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCCM groups (p values <0.001) , but no significant difference between HCM and HOCCM groups.
- **e` wave** in HCM ranged from 1.47 to 2.79 cm/sec with a mean (2.02 ± 0.46 cm/sec) vs 1.22 - 5.83 cm/sec with a mean 2.29 ± 1.22 cm/sec) in HOCCM and 3.10 - 5.80 cm/sec with a mean (4.55 ± 0.79 cm/sec) in the control group. it was significantly higher in the control group than HCM and HOCCM groups (p values <0.001) , but no significant difference between HCM and HOCCM groups.
- **a` wave** in HCM ranged from 1.19 to 3.42 cm/sec with a mean (2.18 ± 0.76 cm/sec) vs 1.31 - 4.78 with a mean (2.41 ± 0.92 cm/sec) in HOCCM and 3.0 – 5.50 with a mean (4.46 ± 0.69 cm/sec) in the control group. it was significantly higher in the control group than HCM and HOCCM groups (p values <0.001) , also it is higher significantly in HOCCM group than in the HCM group (p value 0.042).

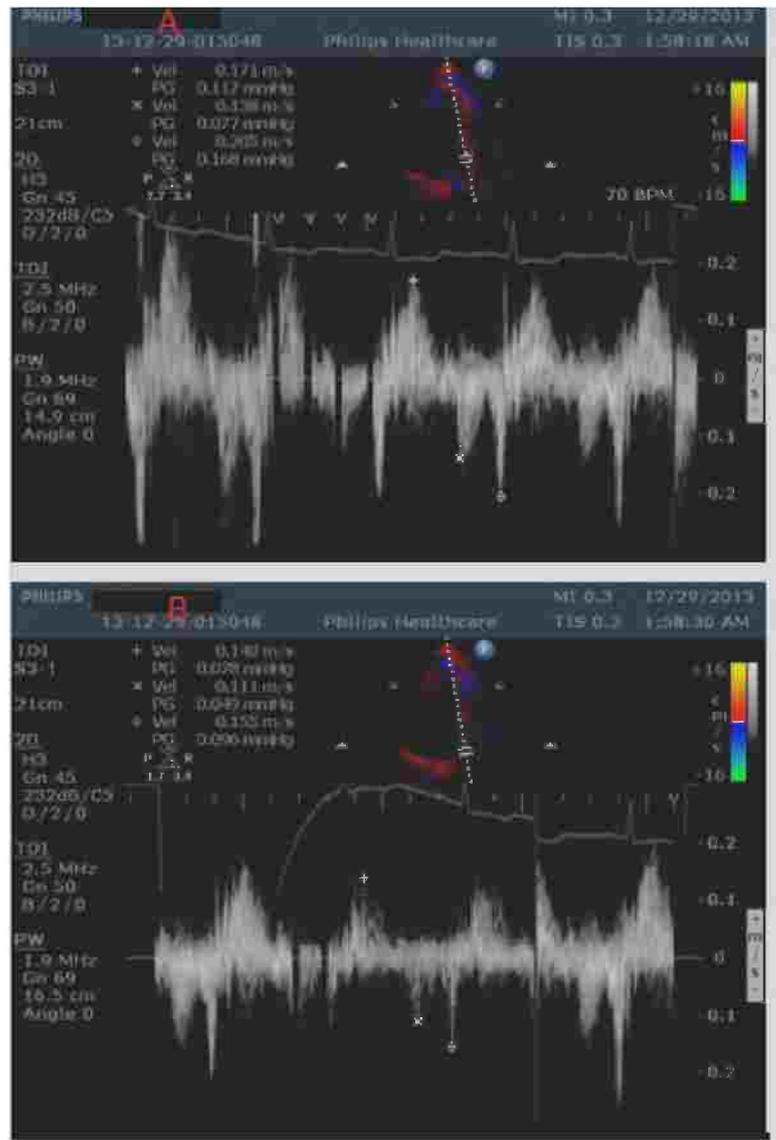


Figure (33): Tissue velocities of LA anterior wall mid segment (A) and superior segment (B) in a patient with HCM

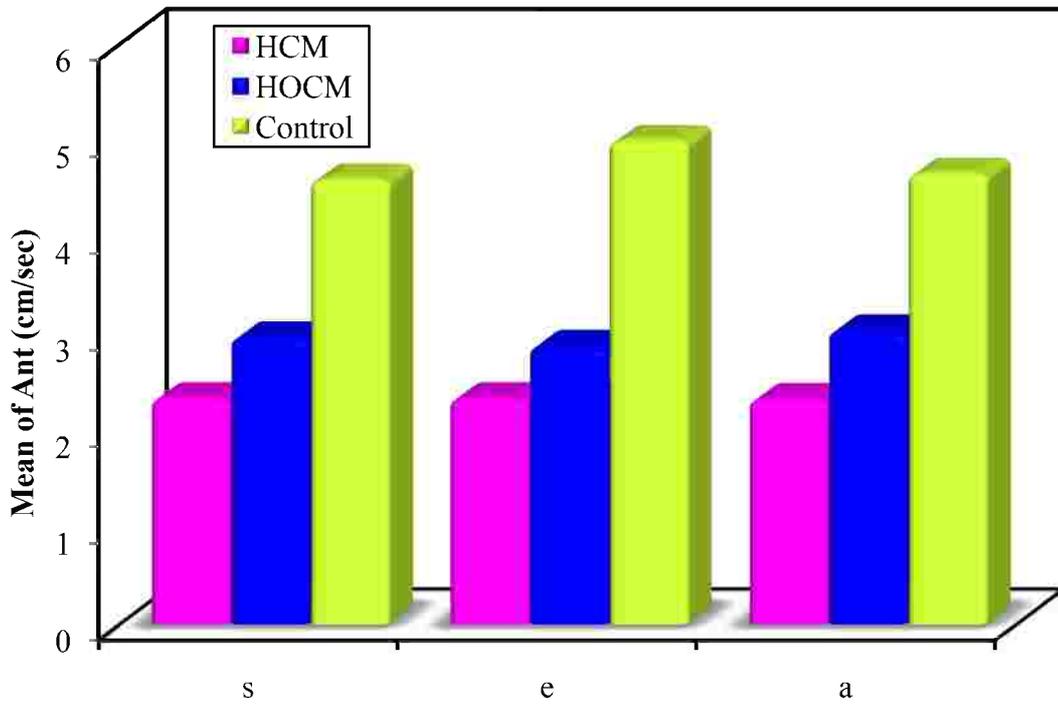


Figure (34): Left atrial regional velocities of anterior wall mid segment

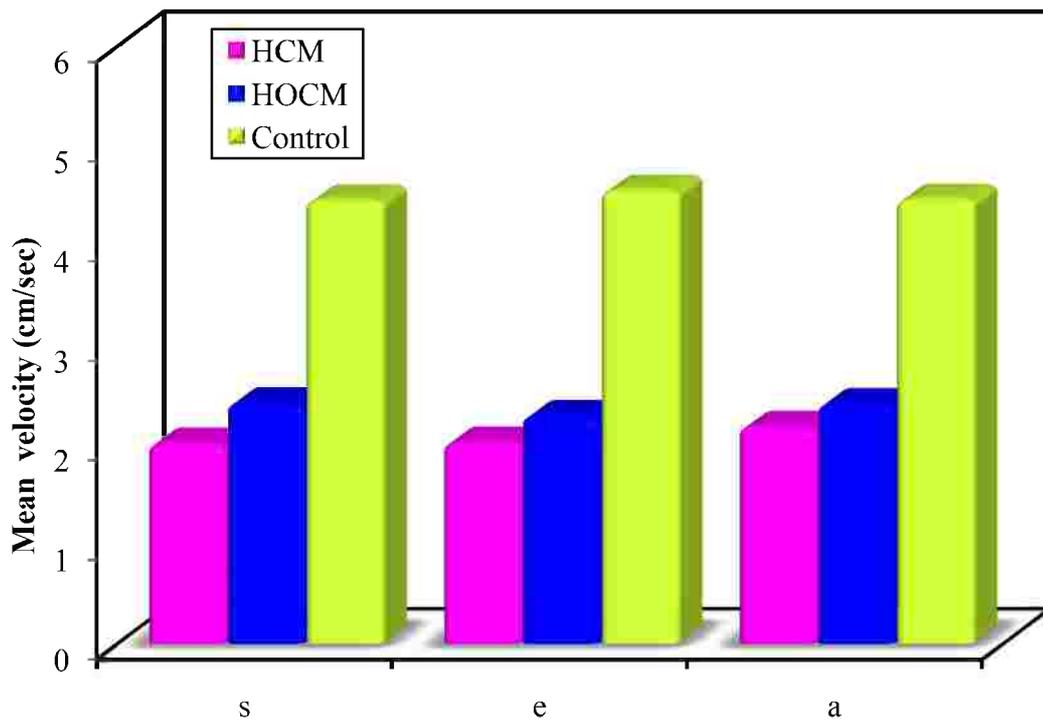


Figure (35): Left atrial regional velocities of anterior wall Superior segment

Table (13): Comparison between the three studied groups according to LA regional velocities in the anterior wall.

Ant		HCM (n = 20)	HOCM (n = 20)	Control (n = 20)	Test of sig.	P
Mid - segment	s-wave (cm/sec)				$^{KW}\chi^2=31.322^*$	<0.001*
	Min. – Max.	1.40 – 3.99	1.87 - 6.21	3.10 - 5.40		
	Mean ± SD.	2.34 ± 0.74	2.97 ± 1.19	4.60 ± 0.63		
	Median	2.29	2.46	4.70		
	Sig. bet. grps	$p_1= 0.104, p_2 <0.001^*, p_3 <0.001^*$				
	e-wave (cm/ sec)				F=39.030*	<0.001*
	Min. – Max.	1.43 - 3.78	1.29 - 6.01	3.0 - 6.40		
	Mean ± SD.	2.34 ± 0.64	2.88 ± 1.34	5.0 ± 0.91		
	Median	2.33	2.71	5.0		
	Sig. bet. grps	$p_1= 0.245, p_2 <0.001^*, p_3 <0.001^*$				
	a-wave (cm/ sec)				$^{KW}\chi^2=34.013^*$	<0.001*
	Min. – Max.	1.47 - 3.66	1.87 - 5.87	3.20 - 5.40		
Mean ± SD.	2.33 ± 0.65	3.04 ± 1.06	4.66 ± 0.60			
Median	2.23	2.72	4.78			
Sig. bet. grps	$p_1= 0.042^*, p_2 <0.001^*, p_3 <0.001^*$					
SuP - segment	s-wave (cm/ sec)				$^{KW}\chi^2=34.515^*$	<0.001*
	Min. – Max.	1.39 - 3.33	1.37 - 6.17	3.0 - 5.50		
	Mean ± SD.	2.01 ± 0.54	2.42 ± 1.13	4.45 ± 0.72		
	Median	1.94	1.90	4.68		
	Sig. bet. grps	$p_1= 0.482, p_2 <0.001^*, p_3 <0.001^*$				
	e-wave (cm/ sec)				$^{KW}\chi^2=33.163^*$	<0.001*
	Min. – Max.	1.47 - 2.79	1.22 - 5.83	3.10 - 5.80		
	Mean ± SD.	2.02 ± 0.46	2.29 ± 1.22	4.55 ± 0.79		
	Median	1.87	1.82	4.63		
	Sig. bet. grps	$p_1= 0.850, p_2 <0.001^*, p_3 <0.001^*$				
	a-wave (cm/ sec)				$^{KW}\chi^2=34.142^*$	<0.001*
	Min. – Max.	1.19 - 3.42	1.31 - 4.78	3.0 – 5.50		
Mean ± SD.	2.18 ± 0.76	2.41 ± 0.92	4.46 ± 0.69			
Median	1.94	2.01	4.54			
Sig. bet. grps	$p_1= 0.457, p_2 <0.001^*, p_3 <0.001^*$					

F: F test (ANOVA) sig. bet. Grps using Post Hoc test (Scheffe)

$^{KW}\chi^2$: Chi square for Kruskal Wallis test sig. bet. Gops using Mann Whitney test

p_1 : p value for comparing between HCM and HOCM

p_2 : p value for comparing between HCM and control

p_3 : p value for comparing between HOCM and control

*: Statistically significant at $p \leq 0.05$

• **LA regional velocities in the lateral wall (table 14)**

Velocities in mid segment of the lateral wall of the left atrium:

- **S`wave** in HCM ranged from 1.71 to 4.01 cm/sec with a mean (2.46 ± 0.69 cm/sec) vs 1.22 - 6.01 cm/sec with a mean (3.01 ± 1.38 cm/sec) in HOCM and 4.40 - 8.0 with a mean (6.26 ± 1.28 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001) , but no significant difference between HCM and HOCM groups.
- **è wave** in HCM ranged from 1.38 to 4.02 cm/sec with a mean (2.47 ± 0.67 cm/sec) vs 1.03 -5.92 cm/sec with a mean (2.93 ± 1.37 cm/sec) in HOCM and 3.80 – 6.80 cm/sec with a mean (5.41 ± 1.04 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001) , but no significant difference between HCM and HOCM groups.
- **à wave** in HCM ranged from 1.23 to 3.24 cm/sec with a mean (2.25 ± 0.59 cm/sec) vs 1.69 – 4.97 cm/sec with a mean (2.87 ± 1.18 cm/sec) in HOCM and 3.70 – 6.90 cm/sec with a mean (5.53 ± 1.20 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001) , but no significant difference between HCM and HOCM groups.

Velocities in superior segment of the lateral wall of the left atrium:

- **S` wave** in HCM ranged from 1.40 to 3.94 cm/sec with a mean(2.13 ± 0.65 cm/sec) vs 1.27 – 5.52 cm/sec with a mean (2.63 ± 1.16 cm/sec) in HOCM and 3.90 – 5.90 cm/sec with a mean (5.06 ± 0.60 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001) , but no significant difference between HCM and HOCM groups.

- **è wave** in HCM ranged from 1.11 to 3.10 cm/sec with a mean (2.15 ± 0.61 cm/sec) vs 1.09 – 5.43 cm/sec (mean 2.45 ± 1.18 cm/sec) in HOCM and 3.10 – 6.80 cm/sec (mean 5.29 ± 0.93 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001), but no significant difference between HCM and HOCM groups.

- **à wave** in HCM ranged from 1.21 to 3.17 with a mean (2.06 ± 0.62 cm/sec) vs 1.33 – 4.23 cm/sec with a mean (2.33 ± 0.74 cm/sec) in HOCM and 2.70 – 6.20 cm/sec with a mean (4.84 ± 1.0 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001), but no significant difference between HCM and HOCM groups.

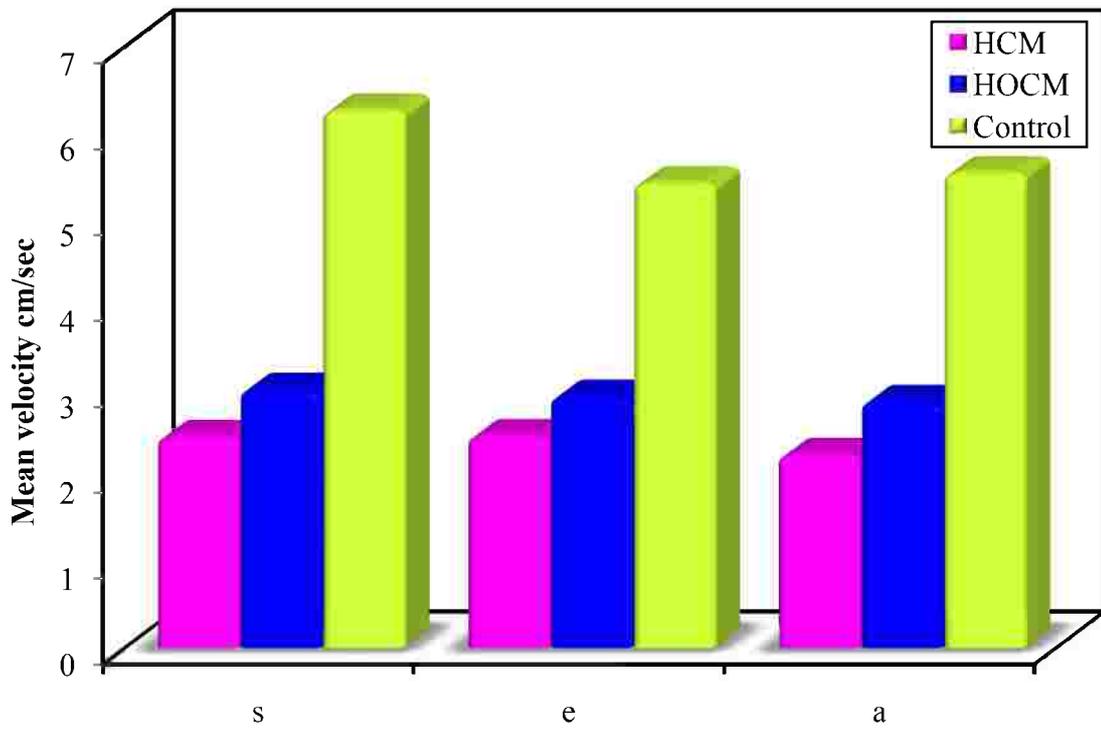


Figure (36): Left atrial regional velocities of lateral wall mid segment

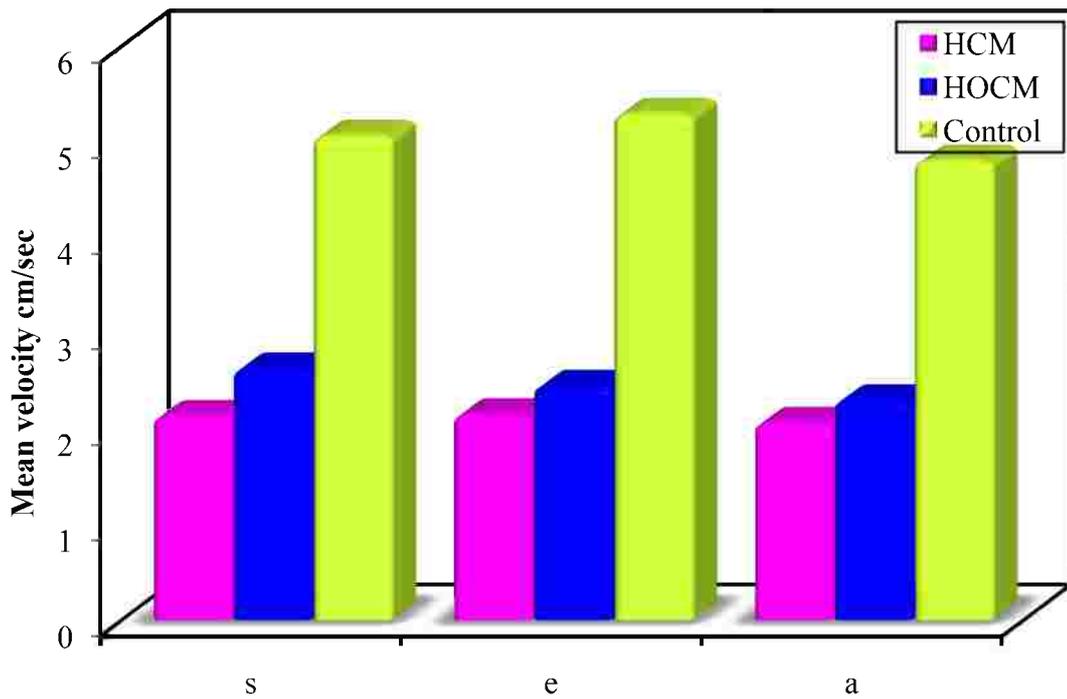


Figure (37): Left atrial regional velocities of lateral wall Superior segment

Table (14): Comparison between the three studied groups according to LA regional velocities in the lateral wall.

Lat		HCM (n = 20)	HOCM (n = 20)	Control (n = 20)	Test of sig.	P
Mid-segment	s-wave (cm/ sec)					
	Min. – Max.	1.71 - 4.01	1.22 - 6.01	4.40 - 8.0	F= 63.444*	<0.001*
	Mean ± SD.	2.46 ± 0.69	3.01 ± 1.38	6.26 ± 1.28		
	Median	2.35	2.52	6.20		
	Sig. bet. grps	p ₁ = 0.330, p ₂ <0.001*, p ₃ <0.001*				
	e-wave (cm/ sec)					
	Min. – Max.	1.38 – 4.02	1.03 -5.92	3.80 – 6.80	F= 44.012*	<0.001*
	Mean ± SD.	2.47 ± 0.67	2.93 ± 1.37	5.41 ± 1.04		
	Median	2.45	2.51	5.54		
	Sig. bet. grps	p ₁ = 0.402, p ₂ <0.001*, p ₃ <0.001*				
	a-wave (cm/ sec)					
	Min. – Max.	1.23 – 3.24	1.69 – 4.97	3.70 – 6.90	Kw χ^2 = 33.738*	<0.001*
Mean ± SD.	2.25 ± 0.59	2.87 ± 1.18	5.53 ± 1.20			
Median	2.03	2.32	5.80			
Sig. bet. grps	p ₁ = 0.223, p ₂ <0.001*, p ₃ <0.001*					
SuP-segment	s-wave (cm/ sec)					
	Min. – Max.	1.40 – 3.94	1.27 – 5.52	3.90 – 5.90	Kw χ^2 = 36.323*	<0.001*
	Mean ± SD.	2.13 ± 0.65	2.63 ± 1.16	5.06 ± 0.60		
	Median	1.98	2.07	4.95		
	Sig. bet. grps	p ₁ = 0.223, p ₂ <0.001*, p ₃ <0.001*				
	e-wave (cm/ sec)					
	Min. – Max.	1.11 - 3.10	1.09 – 5.43	3.10 – 6.80	Kw χ^2 = 35.748*	<0.001*
	Mean ± SD.	2.15 ± 0.61	2.45 ± 1.18	5.29 ± 0.93		
	Median	2.04	2.01	5.16		
	Sig. bet. grps	p ₁ = 0.756, p ₂ <0.001*, p ₃ <0.001*				
	a-wave (cm/ sec)					
	Min. – Max.	1.21 – 3.17	1.33 – 4.23	2.70 – 6.20	Kw χ^2 = 35.906*	<0.001*
Mean ± SD.	2.06 ± 0.62	2.33 ± 0.74	4.84 ± 1.0			
Median	1.91	2.18	4.85			
Sig. bet. grps	p ₁ = 0.256, p ₂ <0.001*, p ₃ <0.001*					

All velocities of left atrium lateral wall in mid and superior segments were lower significantly in HOCM and HCM patients than in controls.

F: F test (ANOVA)

sig. bet. Grps using Post Hoc test (Scheffe)

Kw χ^2 : Chi square for Kruskal Wallis test

sig. bet. Gops using Mann Whitney test

p₁ : p value for comparing between HCM and HOCM

p₂ : p value for comparing between HCM and control

p₃ : p value for comparing between HOCM and control

*: Statistically significant at p ≤ 0.05

• **LA regional velocities in the interatrial septum. (table 15)**

Velocities in mid segment of the interatrial septum:

- **S`wave** in HCM ranged from 1.21 to 3.89 cm/sec with a mean (2.04 ± 0.79 cm/sec) vs 1.22 - 5.40 cm/sec with a mean (2.41 ± 1.09 cm/sec) in HOCCM and 3.80 – 5.80 cm/sec with a mean (4.67 ± 0.57 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCCM groups (p values <0.001) , but no significant difference between HCM and HOCCM groups.
- **è wave** in HCM ranged from 1.30 to 4.01 cm/sec with a mean (2.14 ± 0.80 cm/sec) vs 1.18 – 5.19 cm/sec with a mean (2.10 ± 1.16 cm/sec) in HOCCM and 3.50 – 6.30 cm/sec with a mean (4.77 ± 0.85 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCCM groups (p values <0.001) , but no significant difference between HCM and HOCCM groups.
- **à wave** in HCM ranged from 1.11 to 3.98 cm/sec with a mean (1.98 ± 0.67 cm/sec) vs 1.06 – 3.75 cm/sec with a mean (2.10 ± 0.85 cm/sec) in HOCCM and 3.40 – 5.50 cm/sec with a mean (4.48 ± 0.75 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCCM groups (p values <0.001), but no significant difference between HCM and HOCCM groups.

Velocities in superior segment of the interatrial septum:

- **S` wave** in HCM ranged from 1.20 to 3.11 cm/sec with a mean (1.84 ± 0.55 cm/sec) vs 1.03 – 5.40 cm/sec with a mean (2.56 ± 1.41 cm/sec) in HOCM and 2.40 – 4.90 cm/sec with a mean (3.67 ± 0.81 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001, 0.005 in order), but no significant difference between HCM and HOCM groups.
- **è wave** in HCM ranged from 1.20 to 3.56 cm/sec with a mean (1.88 ± 0.65 cm/sec) vs 1.02 – 5.40 cm/sec with a mean (2.41 ± 1.46 cm/sec) in HOCM and 2.90 – 4.50 cm/sec with a mean (3.69 ± 0.55 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001 , 0.002 in order), but no significant difference between HCM and HOCM groups.
- **à wave** in HCM ranged from 1.35 to 2.97 cm/sec with a mean (1.91 ± 0.44 cm/sec) vs 1.11 – 5.50 cm/sec with a mean (2.14 ± 1.24 cm/sec) in HOCM and 2.50 – 4.30 cm/sec with a mean (3.62 ± 0.49 cm/sec) in the control group. it was significantly higher in the control group than HCM and HOCM groups (p values <0.001), but no significant difference between HCM and HOCM groups.

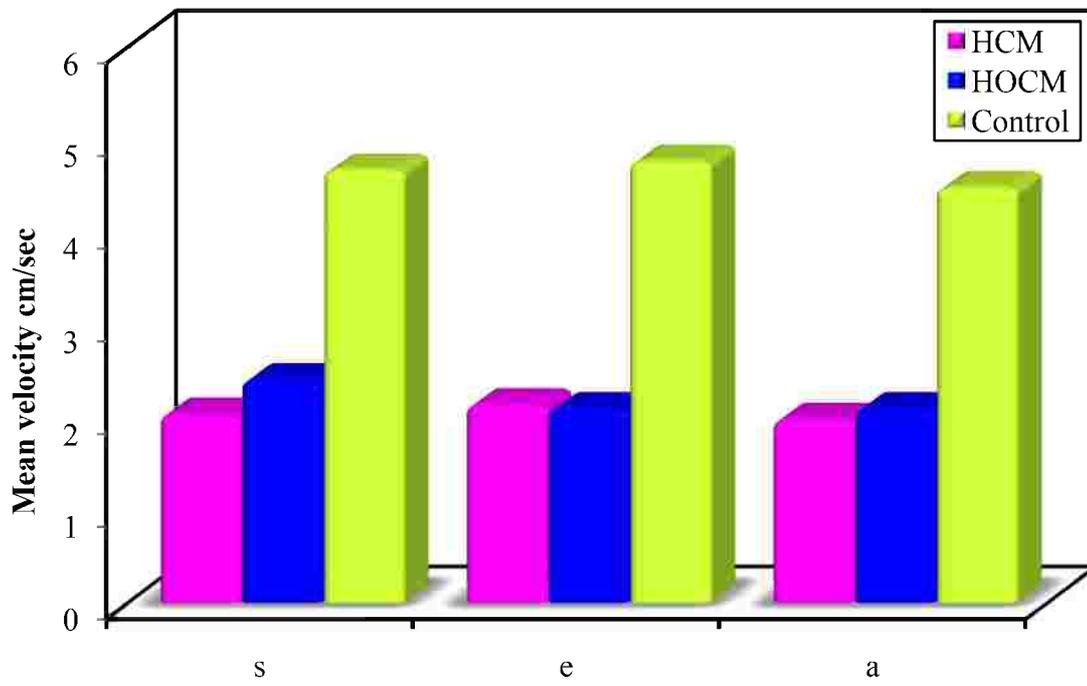


Figure (38): Left atrial regional velocities of interatrial septum mid segment

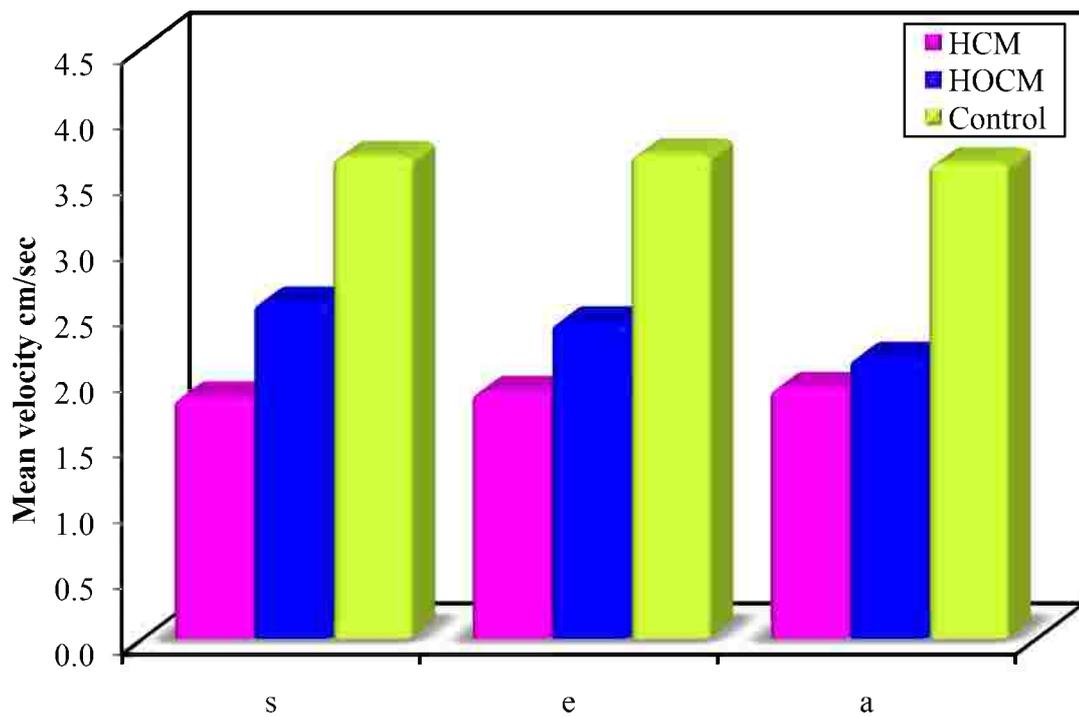


Figure (39): Left atrial regional velocities of interatrial septum Superior segment

Table (15): Comparison between the three studied groups according to LA regional velocities in the interatrial septum.

IAS		HCM (n = 20)	HOCM (n = 20)	Control (n = 20)	$KW\chi^2$	P
Mid-segment	s-wave (cm/ sec)					
	Min. – Max.	1.21 - 3.89	1.22 - 5.40	3.80 – 5.80		
	Mean ± SD.	2.04 ± 0.79	2.41 ± 1.09	4.67 ± 0.57	36.023*	<0.001*
	Median	1.74	1.94	4.70		
	Sig. bet. grps	p ₁ = 0.120, p ₂ <0.001*, p ₃ <0.001*				
	e-wave (cm/ sec)					
	Min. – Max.	1.30 – 4.01	1.18 – 5.19	3.50 – 6.30		
	Mean ± SD.	2.14 ± 0.80	2.10 ± 1.16	4.77 ± 0.85	33.838*	<0.001*
	Median	1.74	1.49	4.90		
	Sig. bet. grps	p ₁ = 0.152, p ₂ <0.001*, p ₃ <0.001*				
	a-wave (cm/ sec)					
	Min. – Max.	1.11 – 3.98	1.06 – 3.75	3.40 – 5.50		
Mean ± SD.	1.98 ± 0.67	2.10 ± 0.85	4.48 ± 0.75	35.227*	<0.001*	
Median	1.81	1.83	4.70			
Sig. bet. grps	p ₁ = 0.776, p ₂ <0.001*, p ₃ <0.001*					
SuP-segment	s-wave (cm/ sec)					
	Min. – Max.	1.20 – 3.11	1.03 – 5.40	2.40 – 4.90		
	Mean ± SD.	1.84 ± 0.55	2.56 ± 1.41	3.67 ± 0.81	22.718*	<0.001*
	Median	1.74	1.80	3.90		
	Sig. bet. grps	p ₁ = 0.234, p ₂ <0.001*, p ₃ = 0.005*				
	e-wave (cm/ sec)					
	Min. – Max.	1.20 – 3.56	1.02 – 5.40	2.90 – 4.50		
	Mean ± SD.	1.88 ± 0.65	2.41 ± 1.46	3.69 ± 0.55	24.091*	<0.001*
	Median	1.65	1.50	3.80		
	Sig. bet. grps	p ₁ = 0.725, p ₂ <0.001*, p ₃ = 0.002*				
	a-wave (cm/ sec)					
	Min. – Max.	1.35 - 2.97	1.11 – 5.50	2.50 – 4.30		
Mean ± SD.	1.91 ± 0.44	2.14 ± 1.24	3.62 ± 0.49	29.802*	<0.001*	
Median	1.88	1.62	3.78			
Sig. bet. grps	p ₁ = 0.626, p ₂ <0.001*, p ₃ <0.001*					

$KW\chi^2$: Chi square for Kruskal Wallis test

p₁ : p value for Mann Whitney test for comparing between HCM and HOCM

p₂ : p value for Mann Whitney test for comparing between HCM and control

p₃ : p value for Mann Whitney test for comparing between HOCM and control

*: Statistically significant at p ≤ 0.05

• **LA regional velocities in the inferior wall table (16)**

Velocities in mid segment of the inferior wall of the left atrium:

- **S` wave** in HCM ranged from 1.28 to 3.99 cm/sec with a mean (2.13 ± 0.75 cm/sec) vs 1.35 – 5.21 cm/sec with a mean (2.72 ± 1.23 cm/sec) in HOCM and 3.20 – 5.40 cm/sec with a mean (4.40 ± 0.63 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001), but no significant difference between HCM and HOCM groups.
- **è wave** in HCM ranged from 1.14 to 3.78 cm/sec with a mean (2.12 ± 0.74 cm/sec) vs 1.32 – 5.25 cm/sec with a mean (2.48 ± 1.20 cm/sec) in HOCM and 2.90 – 6.60 cm/sec with a mean (4.71 ± 1.12 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001), but no significant difference between HCM and HOCM groups.
- **à wave** in HCM ranged from 1.20 to 3.51 cm/sec with a mean (1.90 ± 0.62 cm/sec) vs 1.26 – 4.35 cm/sec with a mean (2.53 ± 1.08 cm/sec) in HOCM and 3.30 – 5.80 cm/sec with a mean (4.61 ± 0.85 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001), but no significant difference between HCM and HOCM groups.

Velocities in superior segment of the inferior wall of the left atrium:

- **S' wave** in HCM ranged from 1.14 to 3.01 cm/sec with a mean (1.79 ± 0.50 cm/sec) vs 1.14 – 5.28 cm/sec with a mean (2.55 ± 1.26 cm/sec) in HOCM and 2.40 – 4.70 cm/sec with a mean (3.61 ± 0.78 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001, 0.003), but no significant difference between HCM and HOCM groups.
- **è wave** in HCM ranged from 1.28 to 3.22 cm/sec with a mean (1.88 ± 0.55 cm/sec) vs 1.11 – 5.12 cm/sec with a mean (2.15 ± 1.20 cm/sec) in HOCM and 2.40 – 4.60 cm/sec with a mean (3.59 ± 0.64 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001), but no significant difference between HCM and HOCM groups.
- **à wave** in HCM ranged from 1.11 to 2.56 cm/sec with a mean (1.74 ± 0.39 cm/sec) vs 1.03 – 3.91 cm/sec with a mean (2.31 ± 0.98 cm/sec) in HOCM and 2.20 – 5.0 cm/sec with a mean (3.96 ± 0.79 cm/sec) in the control group. It was significantly higher in the control group than HCM and HOCM groups (p values <0.001), but no significant difference between HCM and HOCM groups.

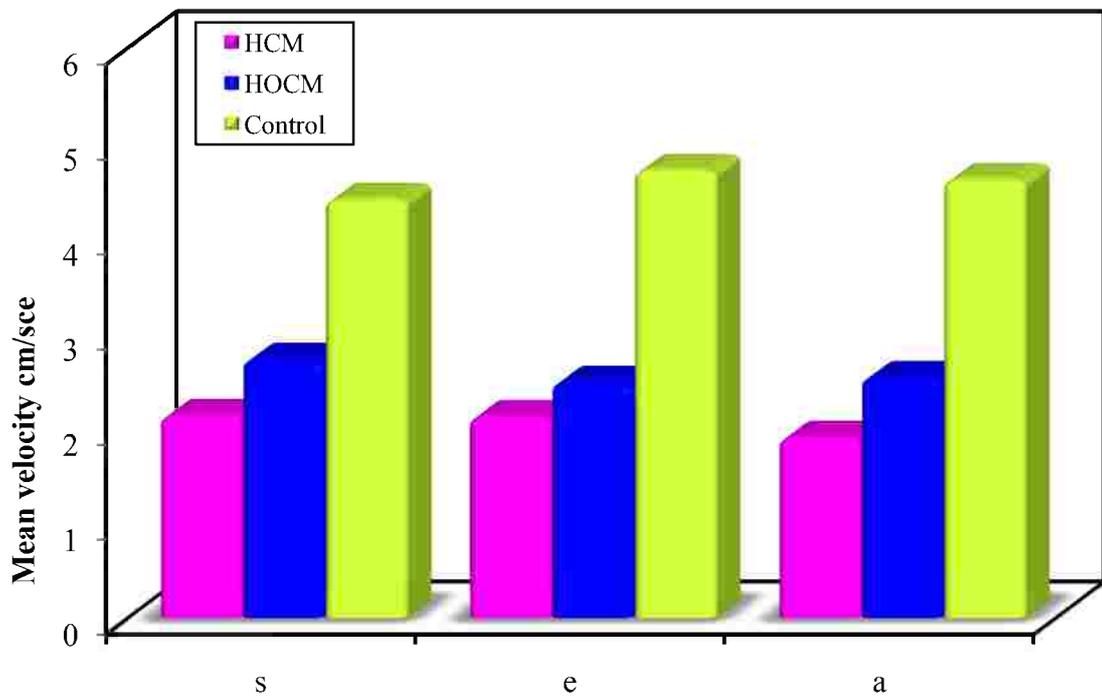


Figure (40): Left atrial regional velocities of inferior wall mid segment

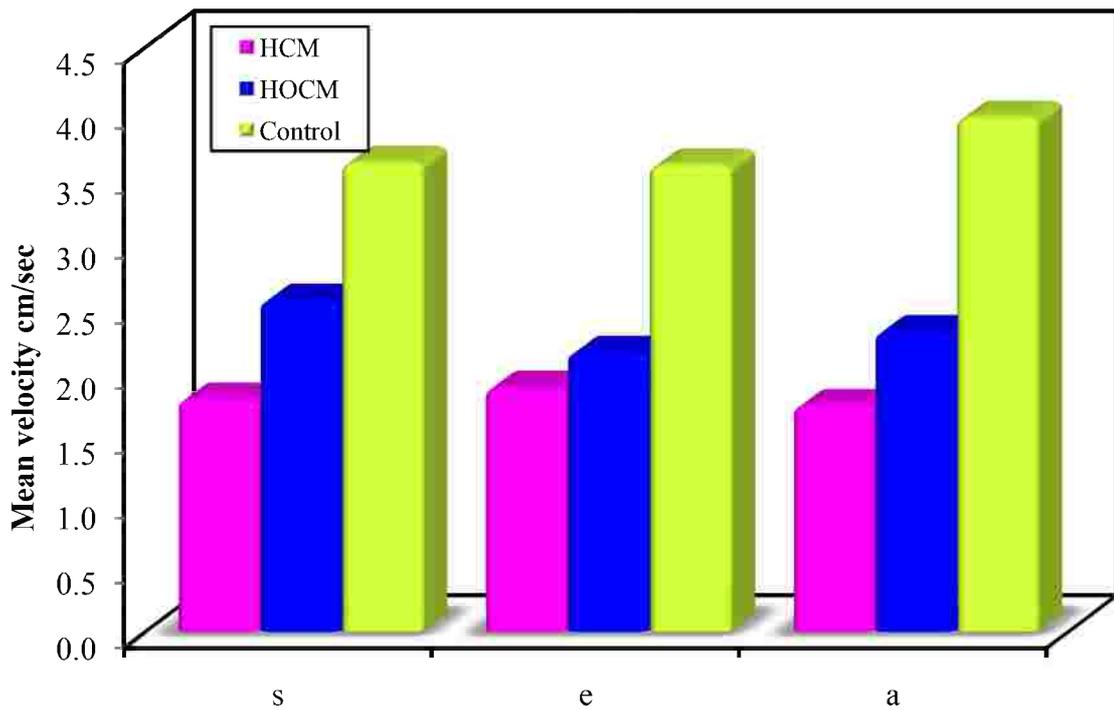


Figure (41): Left atrial regional velocities of inferior wall Superior segment

Table (16): Comparison between the three studied groups according to LA regional velocities in the inferior wall.

INF		HCM (n = 20)	HOCM (n = 20)	Control (n = 20)	χ^2_{KW}	P
Mid-segment	s-wave (cm/ sec)					
	Min. – Max.	1.28 – 3.99	1.35 – 5.21	3.20 – 5.40		
	Mean \pm SD.	2.13 \pm 0.75	2.72 \pm 1.23	4.40 \pm 0.63	28.299*	<0.001*
	Median	1.97	2.27	4.60		
	Sig. bet. grps	p ₁ = 0.110, p ₂ <0.001*, p ₃ <0.001*				
	e-wave (cm/ sec)					
	Min. – Max.	1.14 – 3.78	1.32 – 5.25	2.90 – 6.60		
	Mean \pm SD.	2.12 \pm 0.74	2.48 \pm 1.20	4.71 \pm 1.12	29.769*	<0.001*
	Median	1.99	1.95	4.90		
	Sig. bet. grps	p ₁ = 0.588, p ₂ <0.001*, p ₃ <0.001*				
	a-wave (cm/ sec)					
	Min. – Max.	1.20 – 3.51	1.26 – 4.35	3.30 – 5.80		
Mean \pm SD.	1.90 \pm 0.62	2.53 \pm 1.08	4.61 \pm 0.85	33.814*	<0.001*	
Median	1.82	1.90	4.90			
Sig. bet. grps	p ₁ = 0.081, p ₂ <0.001*, p ₃ <0.001*					
Sup-segment	s-wave (cm/ sec)					
	Min. – Max.	1.14 – 3.01	1.14 – 5.28	2.40 – 4.70		
	Mean \pm SD.	1.79 \pm 0.50	2.55 \pm 1.26	3.61 \pm 0.78	24.735*	<0.001*
	Median	1.66	1.96	3.85		
	Sig. bet. grps	p ₁ = 0.107, p ₂ <0.001*, p ₃ = 0.003*				
	e-wave (cm/ sec)					
	Min. – Max.	1.28 – 3.22	1.11 – 5.12	2.40 – 4.60		
	Mean \pm SD.	1.88 \pm 0.55	2.15 \pm 1.20	3.59 \pm 0.64	25.521*	<0.001*
	Median	1.70	1.59	3.80		
	Sig. bet. grps	p ₁ = 0.655, p ₂ <0.001*, p ₃ <0.001*				
	a-wave (cm/ sec)					
	Min. – Max.	1.11 – 2.56	1.03 – 3.91	2.20 – 5.0		
Mean \pm SD.	1.74 \pm 0.39	2.31 \pm 0.98	3.96 \pm 0.79	33.441*	<0.001*	
Median	1.73	2.53	4.05			
Sig. bet. grps	p ₁ = 0.189, p ₂ <0.001*, p ₃ <0.001*					

χ^2_{KW} : Chi square for Kruskal Wallis test

p₁ : p value for Mann Whitney test for comparing between HCM and HOCM

p₂ : p value for Mann Whitney test for comparing between HCM and control

p₃ : p value for Mann Whitney test for comparing between HOCM and control

*: Statistically significant at p \leq 0.05