

## **AIM OF THE WORK**

The aim of this work was to study, left atrial (LA) function and LA myocardial deformation in patients presenting with acute ST segment elevation myocardial infarction and to show the relationship between left ventricular function and LA deformation parameters.

## **PATIENTS**

This study included 40 patients admitted to cardiology Department, Alexandria Main University hospital with ST segment elevation myocardial infarction (defined as typical chest pain lasting more than thirty minutes along with persistent ST segment elevation more than 1mm in at least 2 consecutive electrocardiographic leads)<sup>(1)</sup> within 24 hours after they received their reperfusion strategy whether thrombolytic therapy or percutaneous coronary intervention (PCI). In addition, 20 healthy controls were included in the study.

### **Exclusion criteria include:**

1. Previous myocardial infarction.
2. Previous coronary artery bypass graft (CABG).
3. Previous percutaneous coronary intervention (PCI).
4. Moderate to severe valvular disease.
5. Non sinus rhythm.
6. Left bundle branch block.
7. Known diabetic patients.
8. Known hypertensive patients.
9. More than 70 years old patients.

## METHODS

All individuals included in the study were subjected to the following after taking an informed consent:

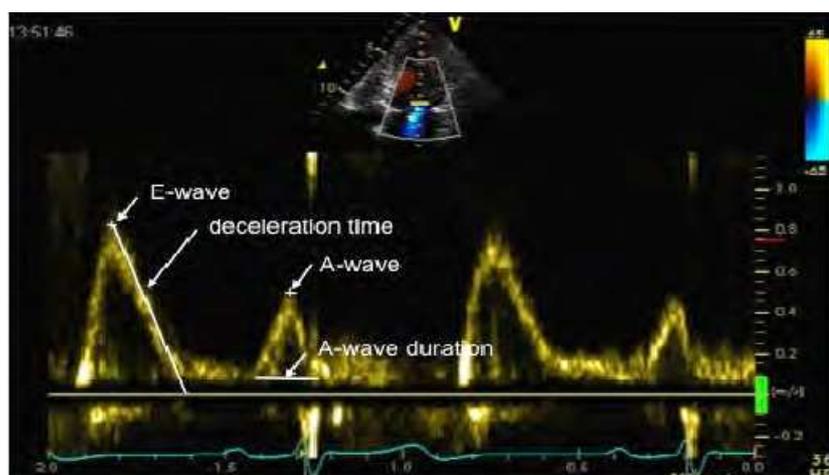
- Thorough history taking.
- Risk factors for coronary artery disease including type II diabetes mellitus, hypertension, dyslipidemia, smoking.
- Complete clinical examination including:
  - Body weight, height and body mass index.
  - Vital signs.
- Routine laboratory investigation and cardiac enzymes (CKMB, Troponin).
- Twelve leads electrocardiogram.

Echocardiography was performed within 24 hours of admission after they received their reperfusion strategy whether PCI or thrombolytic therapy and it included:

### 1. Conventional echocardiography

Echocardiographic recordings were obtained in the left lateral decubitus position and from standard apical and parasternal views the following were measured:

- a. Left ventricular (LV) end diastolic and end systolic diameters, left atrial diameter were measured from M mode echocardiography and LV ejection fraction was calculated by modified Simpson method<sup>(2)</sup>.
- b. With pulsed-wave Doppler, mitral inflow velocities were obtained from the apical 4-chamber view to measure diastolic early filling velocity (E) wave and late diastolic velocity (A) wave, E/A ratio and E-wave deceleration time<sup>(2)</sup>. Figure (1).



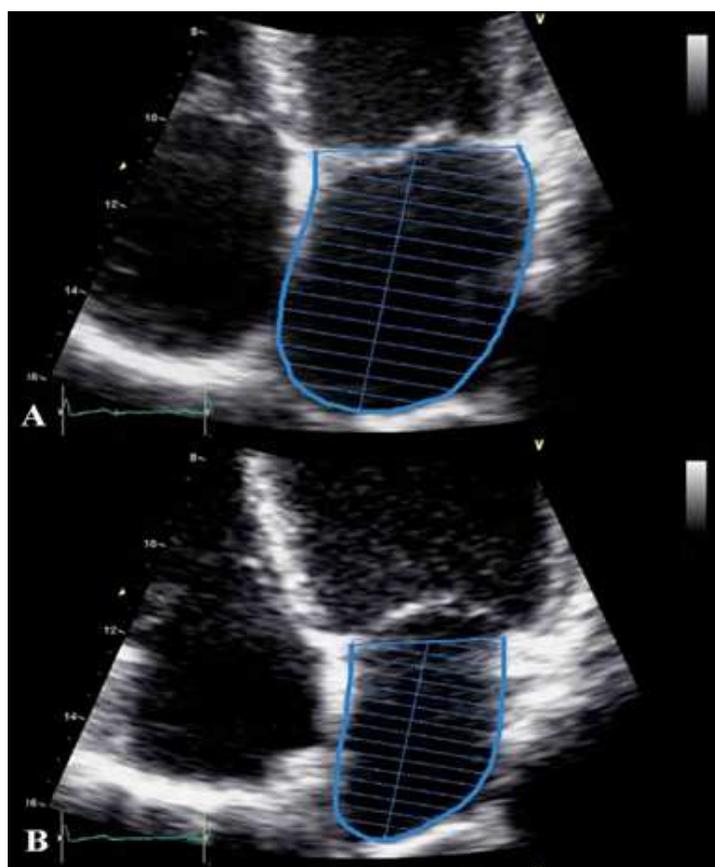
**Figure 1. Transmittal inflow by pulsed wave Doppler.**

Measurements of E-wave velocity (m/s), A-wave velocity (m/s), deceleration time (ms).<sup>(2)</sup>

C. Assessment of left atrial volume: The following LA volumes were measured from apical 4chamber views and indexed to body surface area (BSA):

- Maximum LA volume (LAV max.): measured during LV contraction just before mitral valve opening.
- Minimum LA volume (LAV min.): measured at the QRS onset on electrocardiography.
- LA reservoir volume (LAV res.): LAV max. – LAV min.
- LA ejection fraction (LAEF):  $[LAV \text{ max.}] - [LAV \text{ min.}] / [LAV \text{ max.}]^{(2)}$ .

Figure (2).



**Figure 2.** Left atrial volumes.

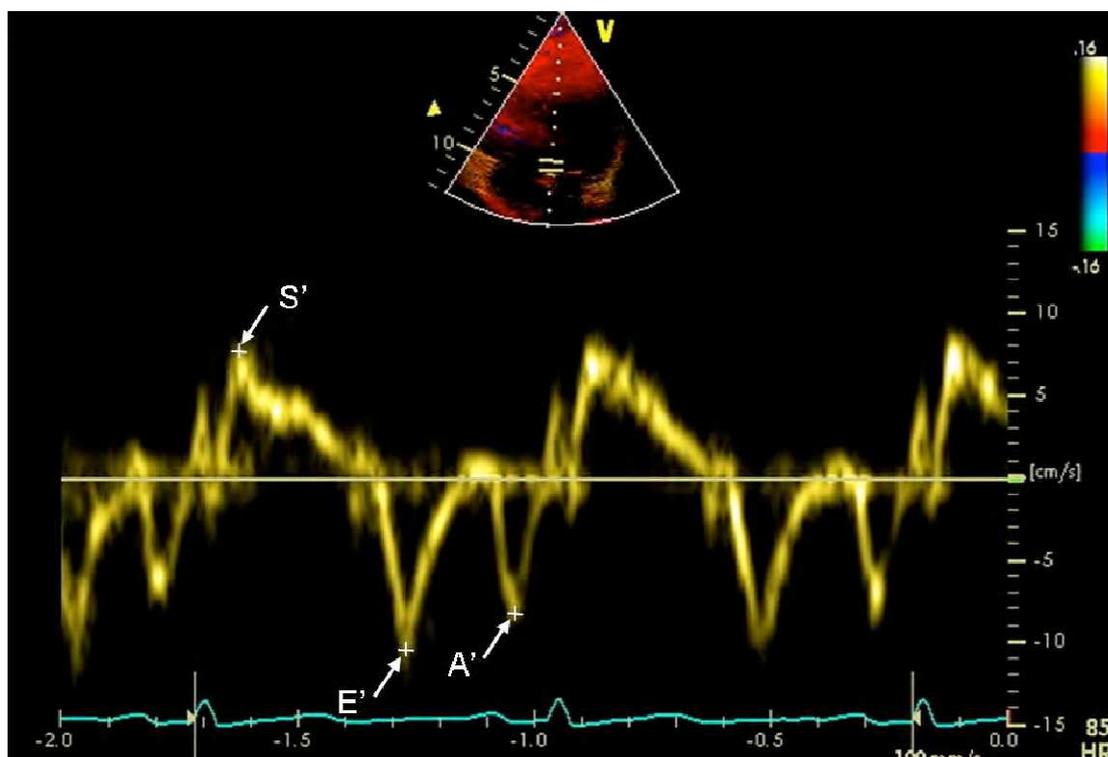
LA volumes from the apical four chamber view. A. LA maximum volume.  
B. LA minimum volume.<sup>(2)</sup>

## **2. Tissue Doppler imaging**

The same echocardiography machine was used to acquire TDI data at high frame rates. The Nyquist limit was set at 15–20 cm/s, and minimal optimal gain was used.

During apical four-chamber imaging, pulsed wave tissue Doppler imaging (PW-TDI) tissue Doppler images were obtained after placement of the sample volume at the level of the

septal and lateral mitral annuli. From these recordings, myocardial systolic ( $Sa/S'$ ), early diastolic ( $Ea/E'$ ), late diastolic velocities ( $Aa/A'$ ), and  $E/Ea$  were measured<sup>(3)</sup> Figure (3).



**Figure 3.** Pulsed wave Doppler tissue imaging of the septal annulus.

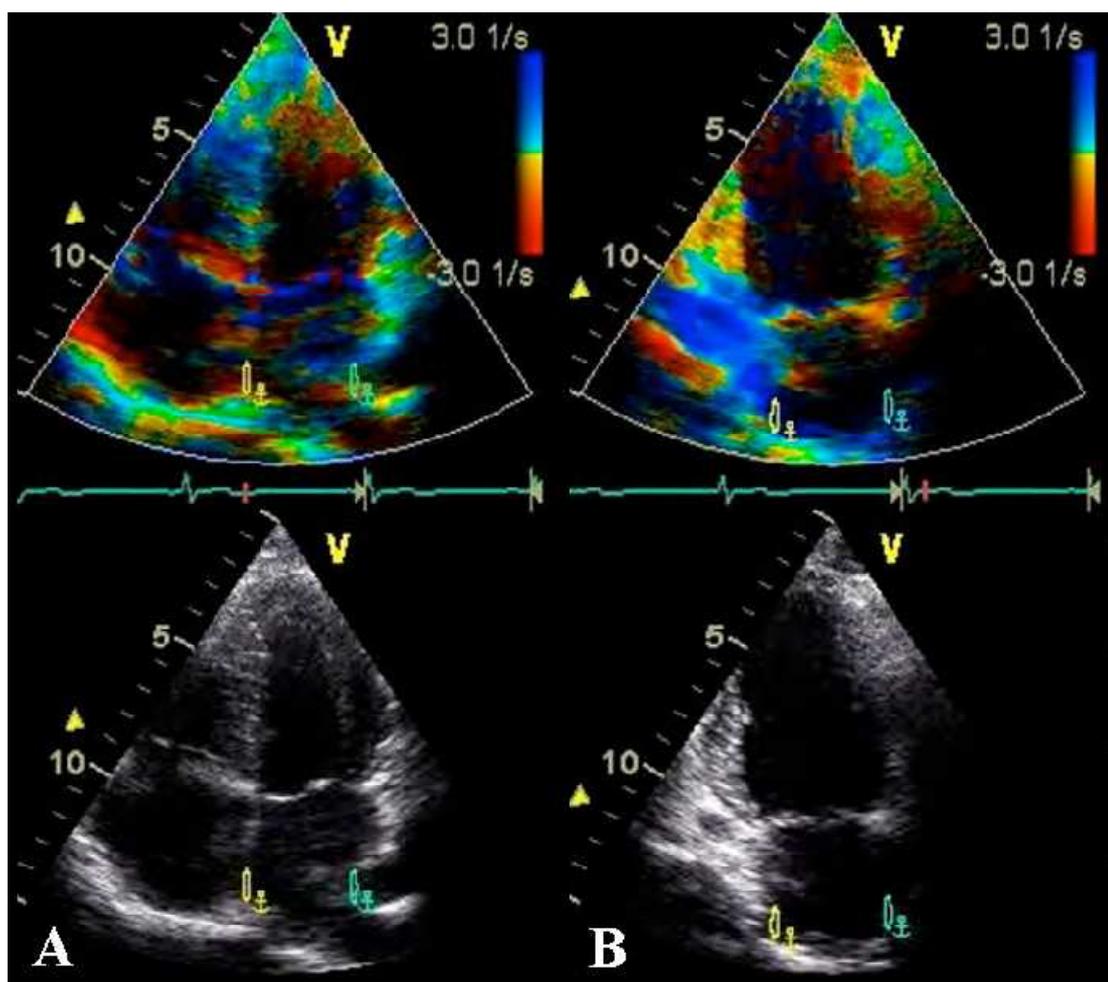
Measurement of systolic velocity ( $S'$ ; m/s), early diastolic velocity ( $E'$ ; m/s) and late diastolic velocity ( $A'$ ; m/s).<sup>(3)</sup>

### 3. Left atrial deformation by strain and strain rate echocardiography:

#### Acquisition and analysis

All patients underwent an echocardiographic examination in left lateral position by a Phillips HD 11 machine using a 3.5 MHz transducer. Evaluation of LA deformation parameters (strain and strain rate) were carried out by tissue doppler imaging using a frame rate of  $160-200\text{ s}^{-1}$  and three consecutive beats were recorded from apical 4- and 2-chamber views<sup>(121)</sup>. During this process, frame rate was increased by narrowing the sector angle to  $15-30^\circ$  and the wall to be recorded was positioned in the center of the sector to minimize the artifacts and then it was re-aligned so as to achieve a parallel direction of the evaluated motion as near to the direction of the insonating beam as possible<sup>(122)</sup>.

LA strain and strain rate were measured offline from colour tissue Doppler images of the LA obtained in the apical four and two chamber views. A narrow ( $10 \times 2\text{ mm}$ ) sample volume was selected due to the thin atrial walls. The sample volume was placed in three segments (basal, mid and apical segments in each of the four walls; septal and lateral walls in the apical four chamber view and the inferior and anterior walls in the apical two chamber view (Figure 4)<sup>(76)</sup>.



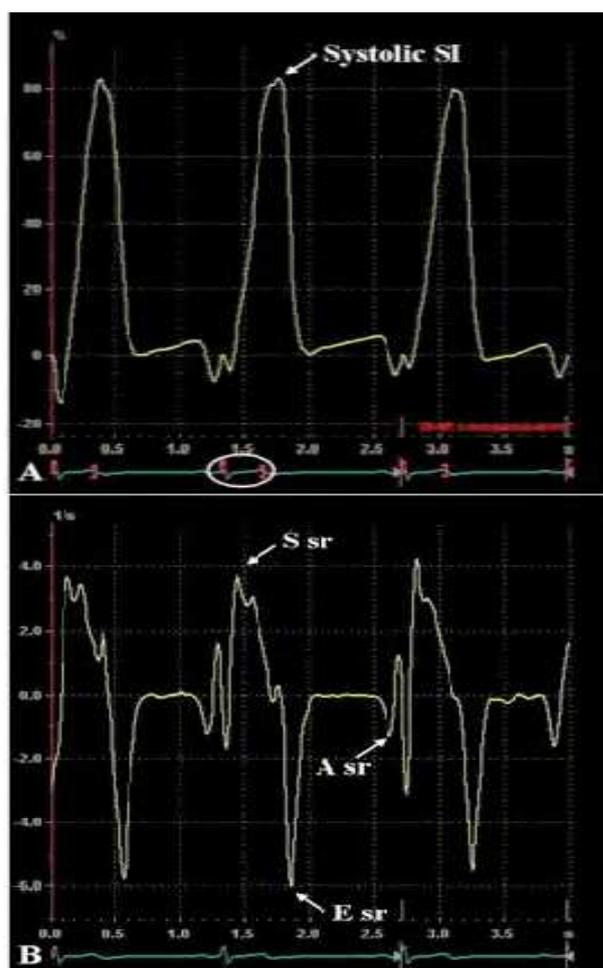
**Figure 4.** Colour tissue Doppler images of the left atrium.

LA strain and strain rate were measured from the basal segments of the:

- A. septal and lateral walls in the apical four chamber view and
- B. the inferior and anterior walls in the two chamber view.<sup>(76)</sup>

The image was tracked frame by frame to prevent sampling of blood pool<sup>(98,112)</sup>. Peak systolic strain was measured by adjusting the ECG gating to the start of the QRS complex (systolic gating) (Figure 5. A), and during atrial contraction. Atrial strain rate was measured in systole (Ssr), early (Esr) and late diastole (Asr) (Figure 5. B). Three consecutive beats were averaged. Global strain and strain rate were calculated by averaging the twelve segments<sup>(82)</sup>.

The typical LA strain and strain rate curves were obtained for each patient. The LA myocardium was divided into six equidistant regions from apical four- and two-chamber views, and average peak LA longitudinal strain values during LV systole (LAs-strain) were calculated for each atrial segment. Global strain and strain rate were also calculated by averaging values from 12 atrial segment<sup>(4)</sup>.



**Figure 5.** Peak strain (%) and strain rate ( $s^{-1}$ ) traces from the left atrium.

- A. Systolic strain was measured by adjusting the ECG gating to the start of the QRS complex on the ECG.
- B. Strain rate was measured in systole (Ssr), early diastole (Esr) and late diastole (Asr).<sup>(82)</sup>

### Coronary Angiography

The coronary angiography was done to those who received thrombolytic therapy according to standard guidelines<sup>(123)</sup>, assessing culprit lesion and other lesions.

**Primary PCI:** The culprit vessel was stented according to guidelines<sup>(124)</sup>.

### Statistical analysis:

After double data entry, data analysis was performed by the special statistical program [Statistical Package for Social Sciences (SPSS) version 18].

Qualitative variables were presented as number and percentages. While continuous variables were expressed as mean  $\pm$  SD.

By using the Kolmogorov-Smirnov test, data were found to be parametric in distribution. Accordingly, parametric statistical tests were performed to identify the presence of significant statistical difference between the mean among STEMI patients in comparison to the control group using a level of significance of 0.05, so that p-value of less than or equal 0.05 was considered statistically significant.

The Student-t- test was used to test the presence of significant statistical difference between the mean among STEMI patients compared to the control group in all the studied variables. One way ANOVA test was used to test the presence of significant difference for more than 2 means.

Pearson correlation test was performed to clarify the presence of positive or negative correlations between the global strain and strain rate and some echocardiographic variables in STEMI patients.

## RESULTS

During the study period, 40 patients with ST elevation MI were selected according to the previously determined criteria. All of them were males with an age ranging from 35 to 69 years and a mean of  $54.78 \pm 6.74$  years.

The 20 healthy controls were also males from 30 to 59 years with a mean of  $50.7 \pm 7.4$  years.

As seen in table 4, the subjects in this study were sex and age matched, so there is no significant difference between the mean age of patients and control. Similarly, there is no significant statistical difference between the mean BMI and BSA for patients and control.

**Table 4. Characteristics of the studied patients and control**

Item	Patients (n= 40)	Control (n= 20)	p-value
Age (years):			
Min. - Max.	35 – 69	30 - 59	0.064
Mean $\pm$ SD	$54.78 \pm 6.74$	$50.7 \pm 7.4$	
Median	54.00	40.00	
Body mass index (Kg/m <sup>2</sup> ):			
Min. - Max.	23.4 – 30.4	23.9 – 33.5	0.535
Mean $\pm$ SD	$26.96 \pm 2.05$	$26.58 \pm 2.52$	
Median	26.94	26.16	
Body surface area (m <sup>2</sup> )			
Min. - Max.	1.75 – 2.08	1.67 – 2.17	0.273
Mean $\pm$ SD	$1.91 \pm 0.09$	$1.88 \pm 0.12$	
Median	1.90	1.87	
Student t- test for the difference between two means p-value > 0.05 is statistically insignificant			

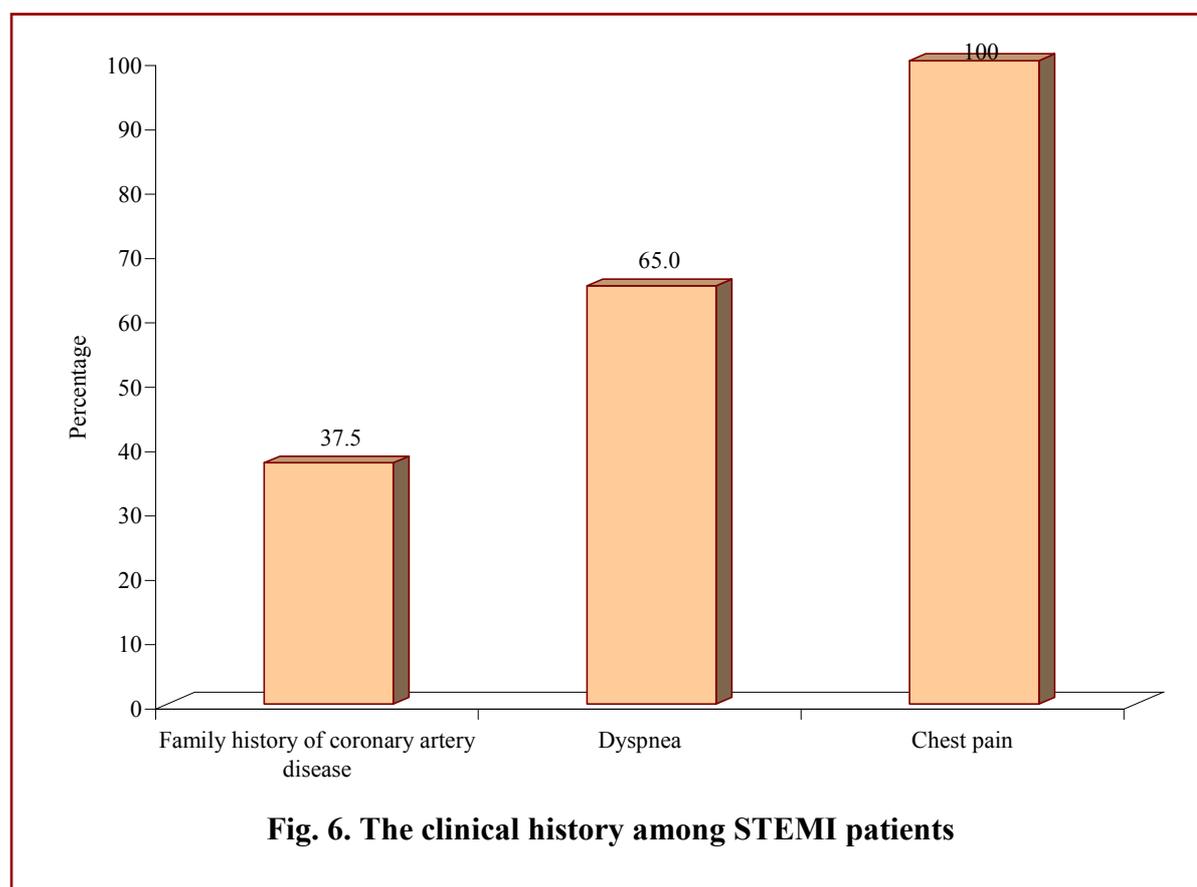
**Clinical characteristics: (Table 5 and Figure 6)**

All the studied patients with MI were presented with chest pain, most of them with dyspnea (65.0%), while 37.5% with family history of coronary artery disease.

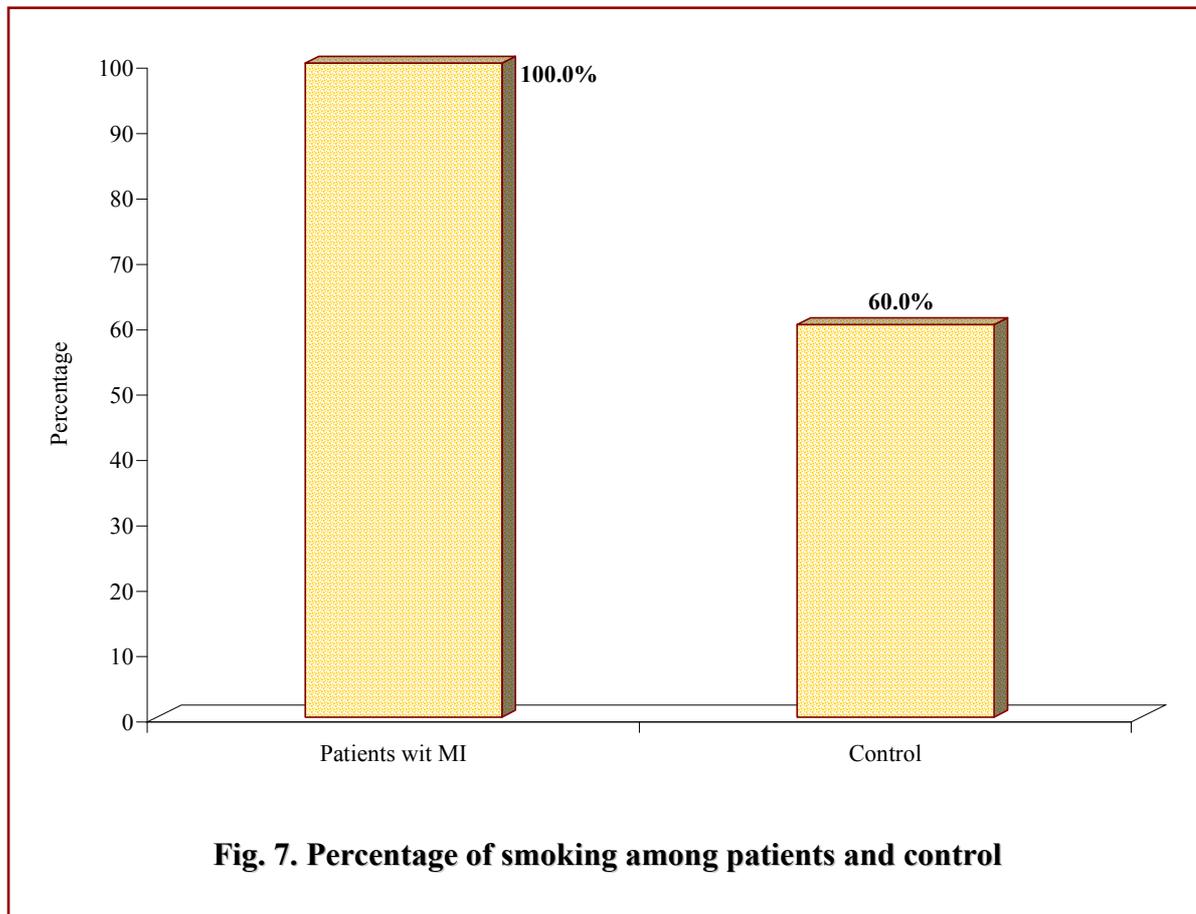
**Table 5. Clinical history of the studied patients**

Clinical history	Patients (n= 40)	
	№	%
Family history of coronary artery disease	15	37.5
Dyspnea	26	65.0
Chest pain	40	100.0

*Some patients have more than one clinical history at the same time.*



Smoking was reported among all the studied patients with MI and in about 60.0% of the control (Figure 7).



### Myocardial infarction findings: (Table 6 and Figure 8)

The common site of myocardial infarction in the studied patients was anterior followed by inferior (35.0% and 30.0% respectively). While anteroseptal and anterolateral infarctions represented (12.5% and 22.5% respectively).

The mean CK-MB was (124.1 ng/ml), and the mean Troponin I was (59.8 ng/ml).

**Table 6. Myocardial infarction findings in the studied patients**

Finding	Patients (n= 40)	
	No	%
Infarct site:		
Anterior	14	35.0
Inferior	12	30.0
Anterolateral	9	22.5
Anteroseptal	5	12.5
Cardiac enzymes:		
CK-MB (ng/ml)	124.1 ± 108.3	
Troponin-I (ng/ml)	59.8 ± 38.2	
CK-MB: Creatinine kinase, MB subunit		



**Fig. 8. Infarction site among STEMI patients**

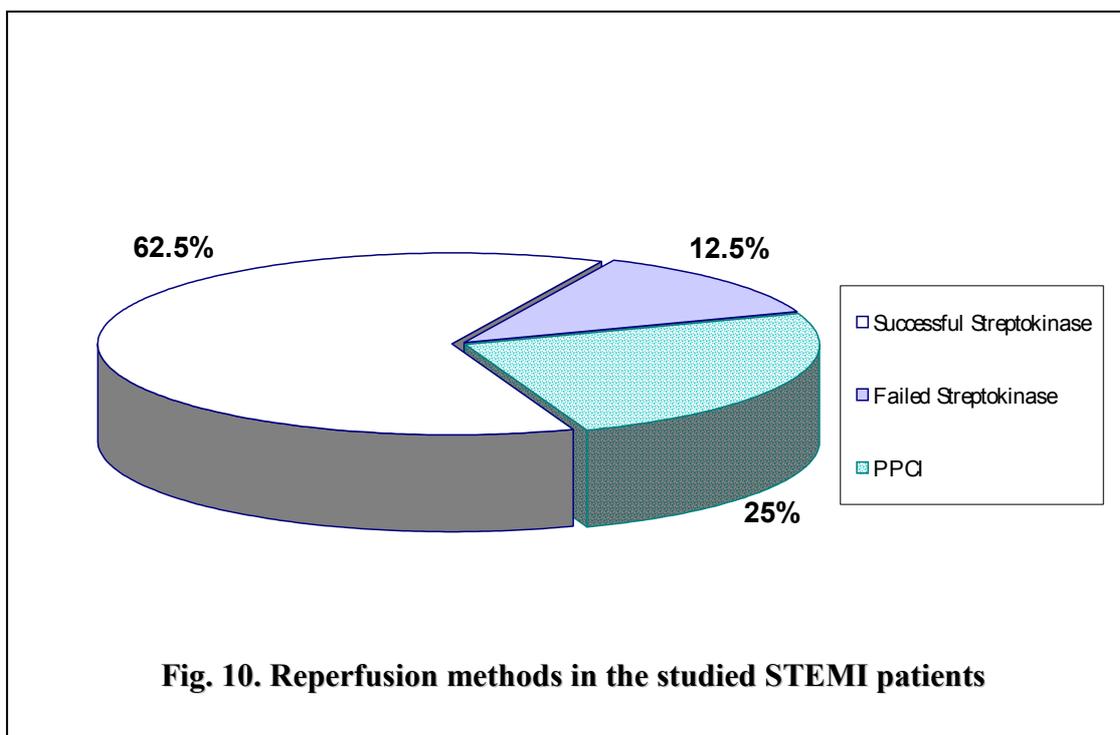
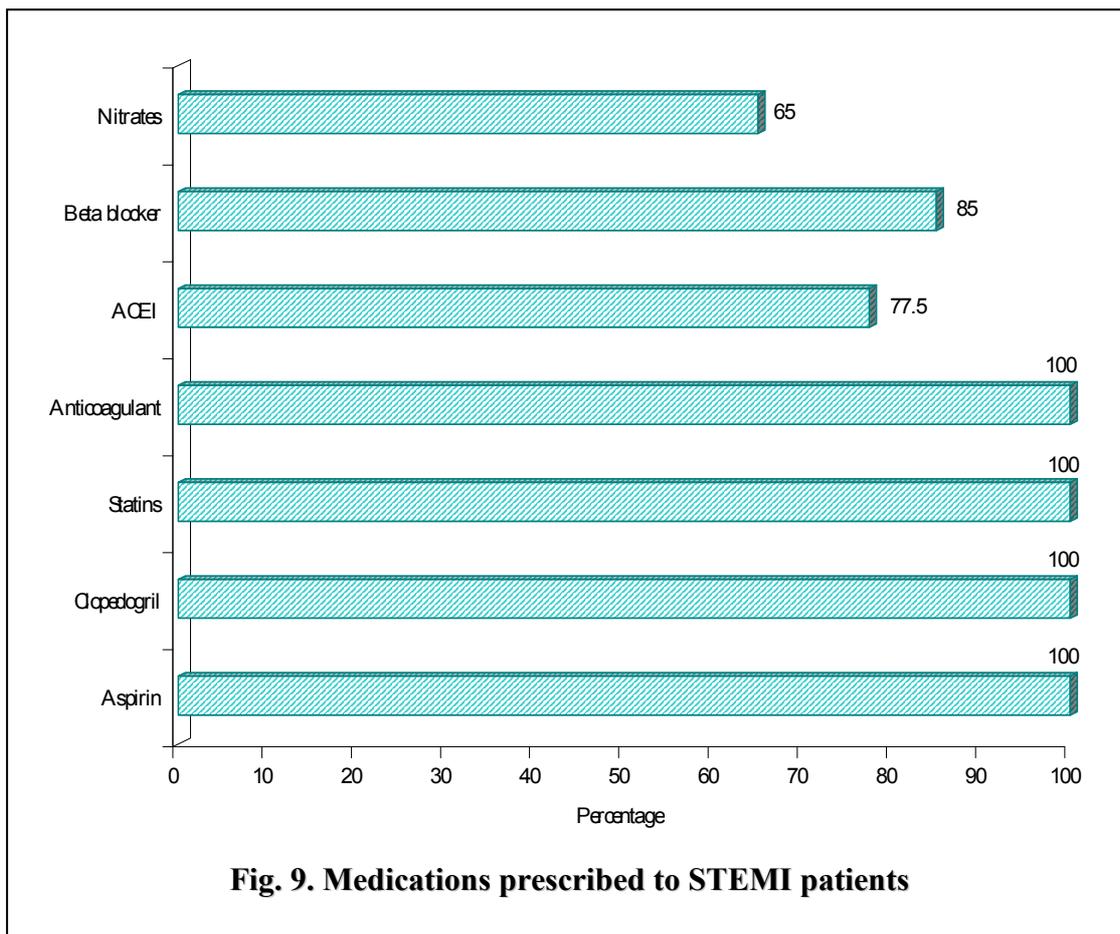
### Medications and reperfusion strategy: (Table 7 and Figure 9 and 10)

It was found that all patients with MI were taking Aspirin, Clopedogril, Statins and anticoagulants. About 85.0% were taking beta blockers, 77.5% were taking ACEI and 65.0% were taking nitrates.

Reperfusion strategy was by streptokinase in the majority of the studied patients (75.0%), of which 62.5% succeeded and 12.5% failed. However, 25.0% of patients were reperfused by PPCI.

**Table 7. Medications prescribed to the studied patients**

Medications	Patients (n= 40)	
	Nº	%
Aspirin	40	100.0
Clopedogril	40	100.0
Statins	40	100.0
Anticoagulant	40	100.0
ACEI	31	77.5
Beta blocker	34	85.0
Nitrates	26	65.0
Reperfusion by:		
- Streptokinase:		
Successful	25	62.5
Failed	5	12.5
- PPCI	10	25.0
PPCI: primary percutaneous coronary intervention ACEI: Angiotensin converting enzyme inhibitors		

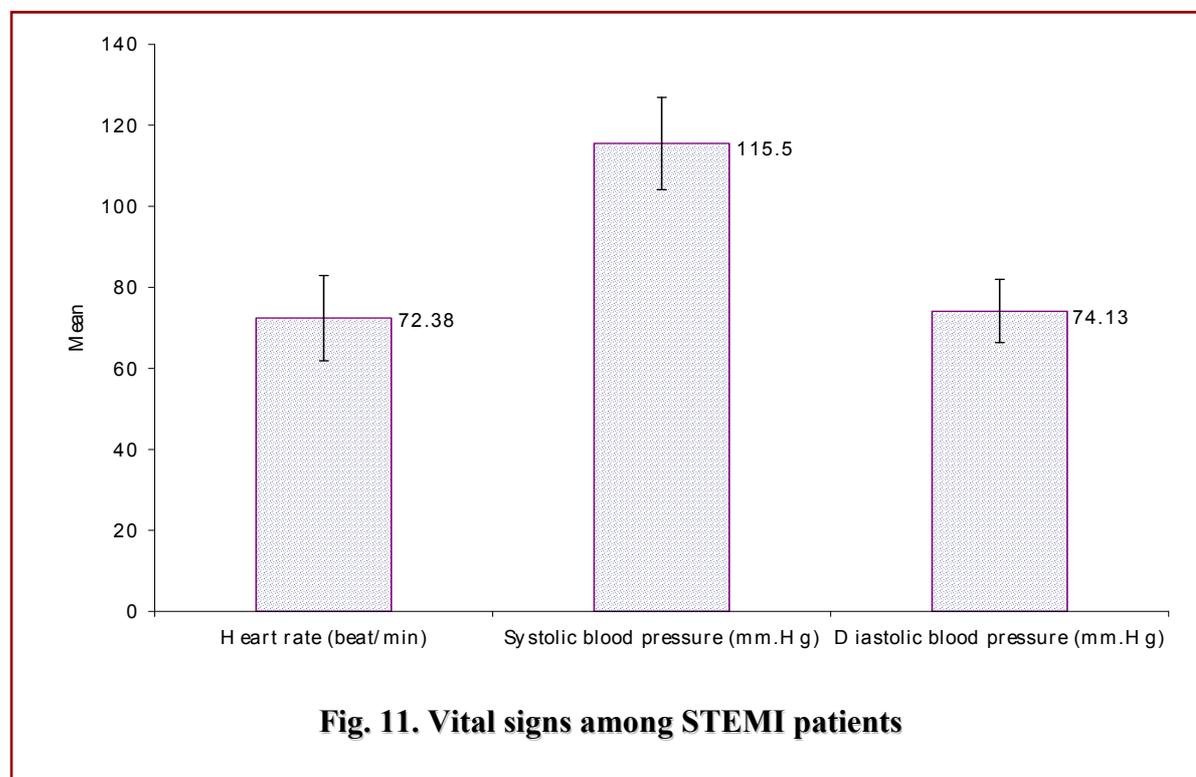


### Vital signs: (Table 8 and Figure 11)

The mean heart rate in the studied patients was 72.38 beat/min and the systolic and diastolic blood pressure were 115.5 and 74.13 mm.Hg respectively.

**Table 8. Vital signs of the studied patients before echocardiographic examination**

Vital signs	Patients (n= 40)
Heart rate (beat/min):	
Min. - Max.	55 – 100
Mean $\pm$ SD	72.38 $\pm$ 10.5
Median	70.0
Systolic blood pressure (mm.Hg):	
Min. - Max.	100 – 140
Mean $\pm$ SD	115.5 $\pm$ 11.4
Median	112.5
Diastolic blood pressure (mm.Hg):	
Min. - Max.	60 – 90
Mean $\pm$ SD	74.13 $\pm$ 7.8
Median	70.0



### Laboratory findings: (Table 9 and 10)

Lipid profile in the studied patients with MI showed that the mean total cholesterol was  $174.75 \pm 49.56$  mg/dl, and the mean triglyceride was  $161.4 \pm 70.92$  mg/dl. The mean HDL was  $38.63 \pm 8.33$  mg/dl and the LDL was  $109.0 \pm 37.11$  mg/dl.

Hematological investigations showed that the mean hemoglobin concentration in the studied patients with MI was 13.7g/dl, the mean WBC count was  $9.9 \times 10^3/\mu\text{l}$  and the mean platelets count was  $253.7 \times 10^3/\mu\text{l}$ .

The chemical investigations showed the mean random blood glucose as 106.3 mg/dl and within normal blood urea and serum creatinin mean values (33.9 mg/dl and 0.99 mg/dl, respectively).

The investigated electrolytes showed the mean  $[\text{Na}^+]$  was 136.2 mmol/L and the mean  $[\text{K}^+]$  was 3.6 mmol/L.

**Table 9. Lipid profile in the studied patients with myocardial infarction**

Laboratory tests	Patients (n= 40)
Total cholesterol (mg/dl):	
Min. - Max.	85.0 – 270.0
Mean $\pm$ SD	$174.7 \pm 49.6$
Median	171.5
Triglycerides (mg/dl):	
Min. - Max.	45.0 – 349.0
Mean $\pm$ SD	$161.4 \pm 70.92$
Median	129.0
HDL (mg/dl):	
Min. - Max.	23.0 – 58.0
Mean $\pm$ SD	$38.63 \pm 8.33$
Median	39.50
LDL (mg/dl):	
Min. - Max.	40.0 – 188.0
Mean $\pm$ SD	$109.0 \pm 37.11$
Median	103.0
HDL: High density lipoprotein cholesterol	
LDL: Low density lipoprotein cholesterol	

**Table 10. Other laboratory findings in the studied patients**

Laboratory tests	Patients (n= 40)
Hemoglobin (g/dl):	
Min. - Max.	8.3 – 16.1
Mean ± SD	13.7 ± 1.4
Median	14.0
Total WBC (X 10 <sup>3</sup> /μl):	
Min. - Max.	5.0 – 16.0
Mean ± SD	9.9 ± 2.2
Median	9.5
Platelets (X 10 <sup>3</sup> /μl):	
Min. - Max.	127 – 366
Mean ± SD	253.7 ± 65.4
Median	249.5
Random blood glucose (mg/dl):	
Min. - Max.	80 – 146
Mean ± SD	106.3 ± 15.3
Median	102.5
Blood urea (mg/dl):	
Min. - Max.	17 – 66
Mean ± SD	33.9 ± 11.4
Median	32.0
Serum creatinin (mg/dl):	
Min. - Max.	0.5 – 2.4
Mean ± SD	0.99 ± 0.35
Median	1.0
Serum sodium (mmol/L):	
Min. - Max.	128 – 145
Mean ± SD	136.2 ± 4.0
Median	136.0
Serum potassium (mmol/L):	
Min. - Max.	3.6 – 4.9
Mean ± SD	4.18 ± 0.30
Median	4.15
WBC: white blood cells	

### Coronary angiographic data and PPCI (Table 11 and Figures 12, 13):

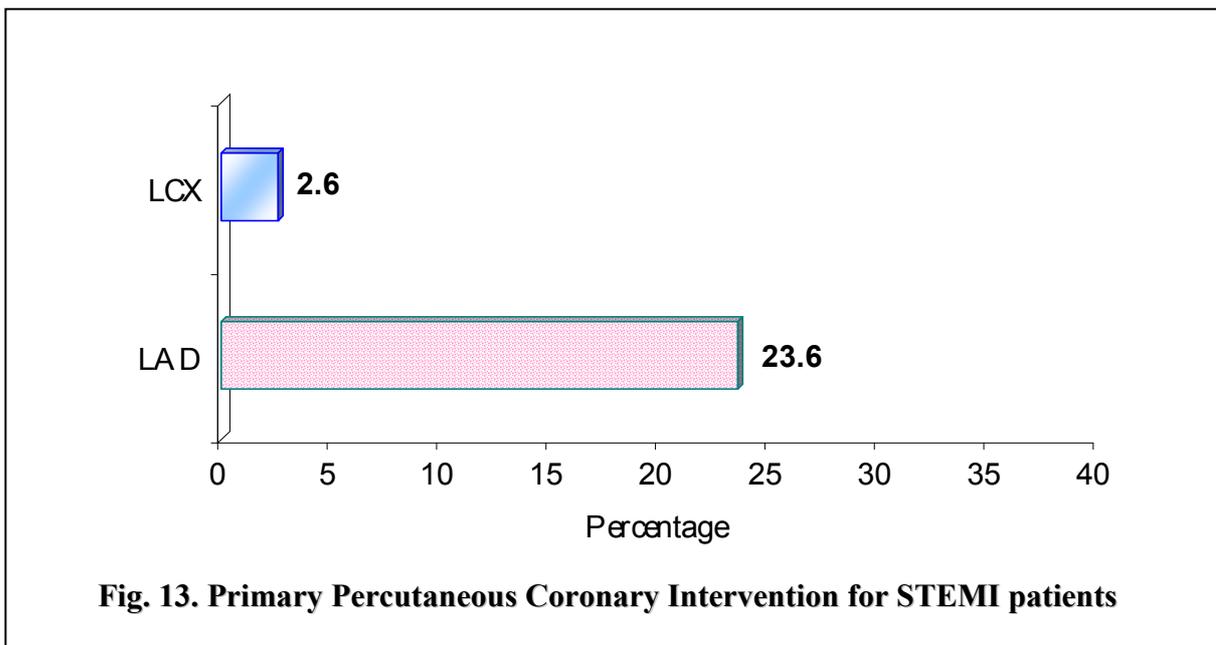
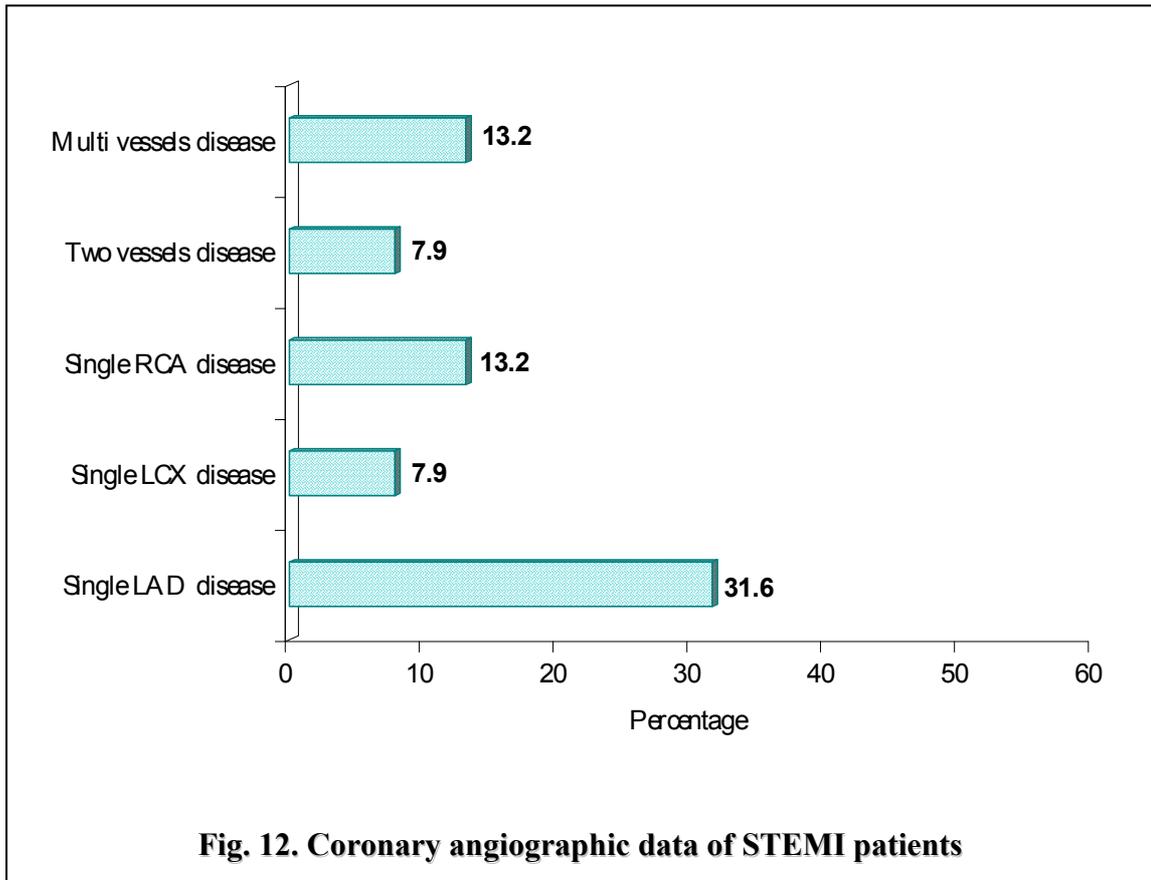
During coronary angiographic imaging for 38 patients with MI, it was found that higher percentage of them 21(55.2%) were having left anterior descending coronary artery disease. Four patients were having left circumflex coronary artery disease (10.5%) and five patients with right coronary artery disease (13.2%). The remainders were with multivessel disease 5(13.2%) and two vessel disease 3(7.9%).

### Primary percutaneous coronary intervention:

In patients with MI, it was found that the culprit vessel reperfusion was LAD in most of them; 9 out of 10 patients (90.0%) representing 23.6% from the total (n=38), and LCX in one patient (10.0%) representing 2.6% from the total (n=38).

**Table 11. Coronary angiographic data and primary percutaneous coronary intervention of patients with myocardial infarction**

Finding	Patients (n= 38)	
	No	%
<b>Coronary angiographic data to those who received thrombolytics (n=28):</b>		
Single LAD disease	12	31.6
Single LCX disease	3	7.9
Single RCA disease	5	13.2
Two vessels disease	3	7.9
Multi vessels disease	5	13.2
<b>Primary PCI culprit lesion reperfusion (n=10):</b>		
LAD	9	23.6
LCX	1	2.6
LAD: Left anterior descending coronary artery RCA: Right coronary artery Intervention		
LCX: Left circumflex artery PCI: Percutaneous Coronary		



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**Left ventricular dimensions, volumes and systolic functions: (Table 12 and Figure 14-16)****- The left ventricular end diastolic dimensions (LVEDD):**

The LVEDD was significantly higher in the studied patients with MI ( $6.38 \pm 0.77$  cm) than in the control ( $5.16 \pm 0.42$  cm). This difference was found statistically highly significant ( $p < 0.01$ ).

**- The left ventricular end systolic dimensions (LVESD):**

The LVESD was significantly higher in the studied patients with MI ( $4.61 \pm 0.96$  cm) than in the control ( $3.09 \pm 0.29$  cm). This difference was found statistically highly significant ( $p < 0.01$ ).

**- The left ventricular end diastolic volume (LVEDV):**

The LVEDV was significantly higher in the studied patients with MI ( $169.83 \pm 49.53$  ml) than in the control ( $104.35 \pm 24.93$  ml). This difference was found statistically highly significant ( $p < 0.01$ ).

**- The left ventricular end systolic volume (LVESV):**

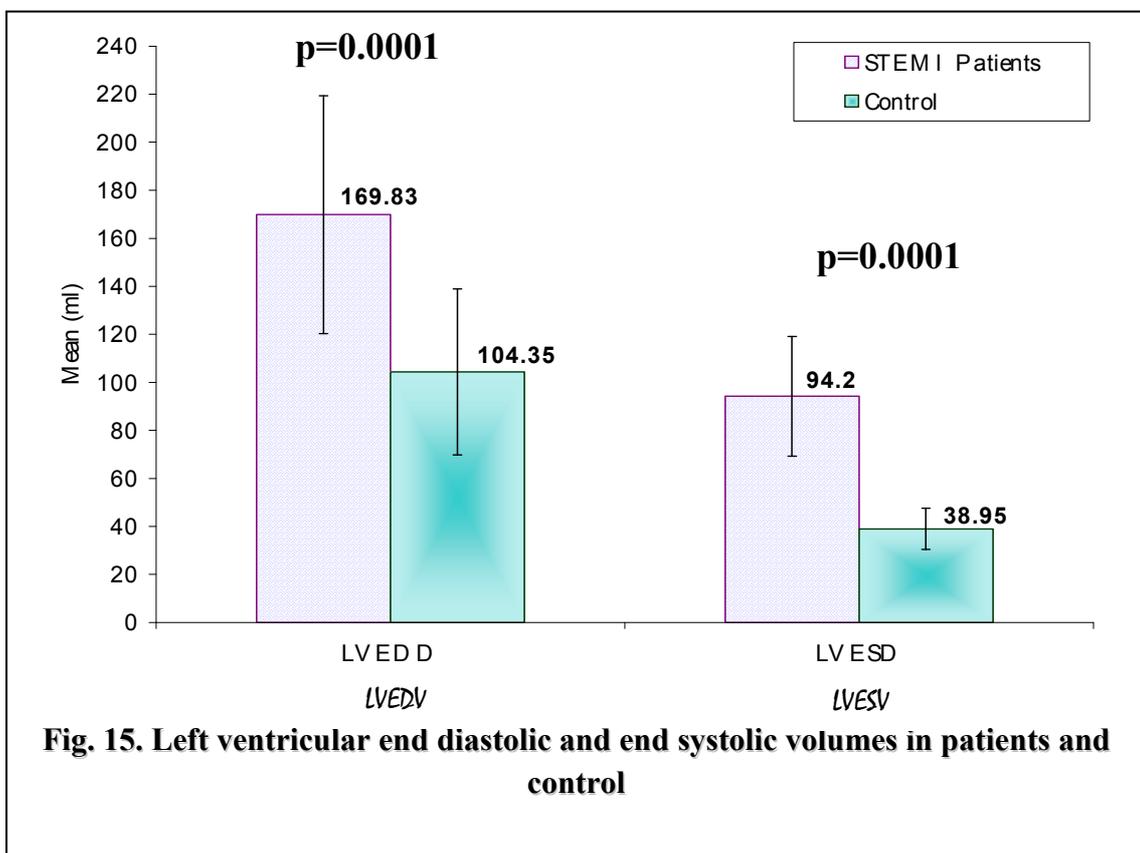
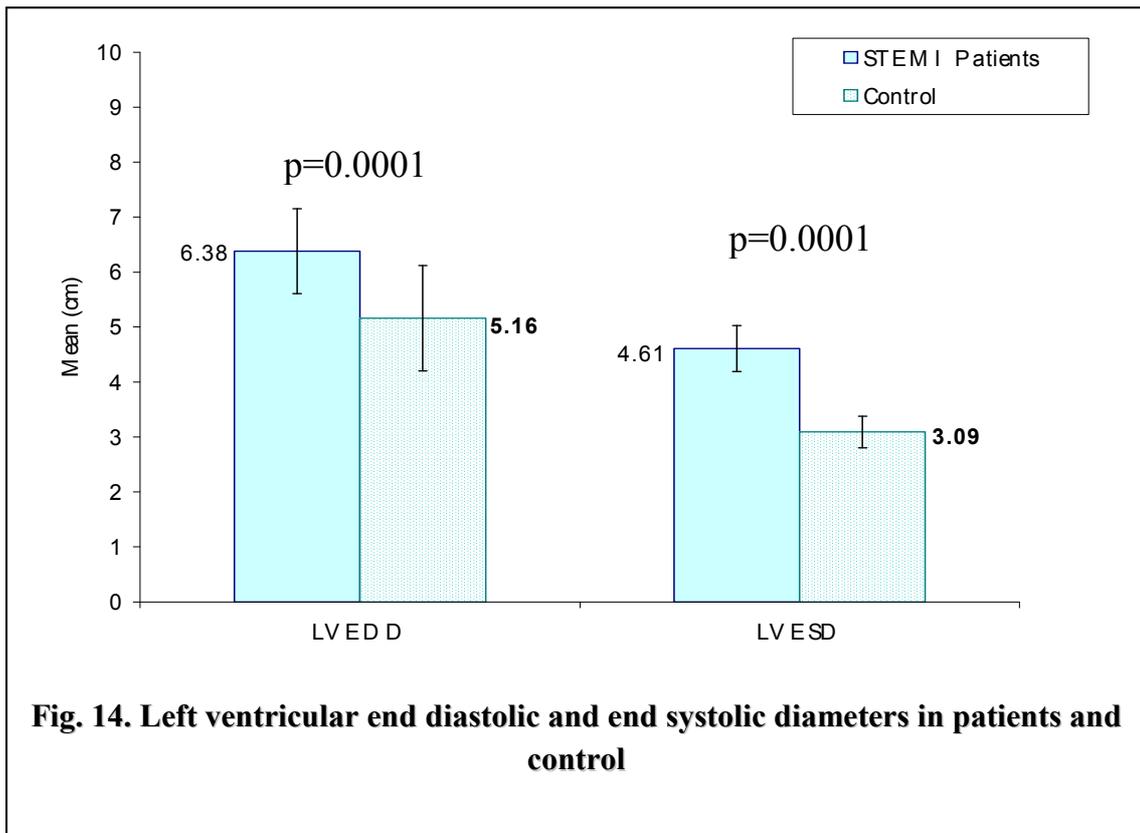
The LVESV was significantly higher in the studied patients with MI ( $94.2 \pm 34.54$  ml) than in the control ( $38.95 \pm 8.57$  ml). This difference was found statistically highly significant ( $p < 0.01$ ).

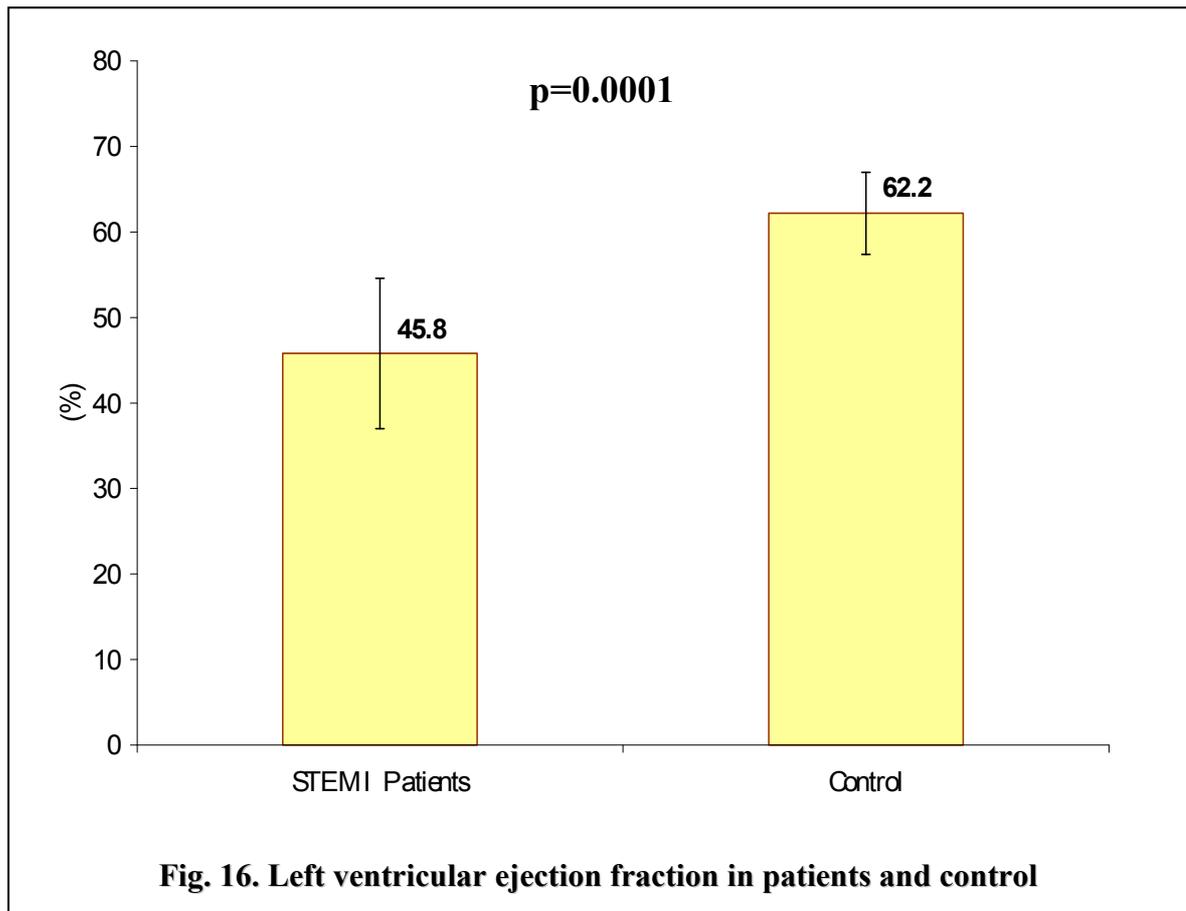
**- The left ventricular ejection fraction (LVEF):**

The LVEF was significantly lower in the studied patients with MI ( $45.8 \pm 8.8\%$ ) than in the control ( $62.2 \pm 4.8\%$ ). This difference was found statistically highly significant ( $p < 0.01$ ).

**Table 12. Comparison between patients with myocardial infarction and the control by left ventricular dimensions, volumes and systolic functions**

Item	Patients (n= 40)	Control (n= 20)	p-value
LVEDD (cm):			
Min. - Max.	5.05 – 7.90	4.52 – 6.30	<b>0.0001*</b>
Mean ± SD	6.38 ± 0.77	5.16 ± 0.42	
Median	6.42	5.11	
LVESD (cm):			
Min. - Max.	2.96 - 6.72	2.55 – 3.66	<b>0.0001*</b>
Mean ± SD	4.61 ± 0.96	3.09 ± 0.29	
Median	4.74	3.06	
LVEDV (ml):			
Min. - Max.	87.1 – 267.0	67 – 155	<b>0.0001*</b>
Mean ± SD	169.83 ± 49.53	104.35 ± 24.93	
Median	170.5	107.0	
LVESV(ml):			
Min. - Max.	36.0 - 162.0	22 – 58	<b>0.0001*</b>
Mean ± SD	94.2 ± 34.54	38.95 ± 8.57	
Median	98.4	38.5	
LVEF (%):			
Min. - Max.	30.1 - 61.0	50.6 – 67.5	<b>0.0001*</b>
Mean ± SD	45.8 ± 8.8	62.2 ± 4.8	
Median	45.0	63.15	
LVESD: left ventricular end systolic diameter		LVEDD; left ventricular end diastolic diameter	
LVEDV: left ventricular end diastolic volume		LVESV: left ventricular end systolic volume	
LVEF: left ventricular ejection fraction			
Student t- test for the difference between two means		*Statistically significant	





### **Conventional Doppler echocardiography: (Table 13 and Figure 17-19)**

The studied transmitral inflow velocities in patients with MI showed the followings:

- **The E-wave of conventional echo:**

The E-wave was found to be significantly lower in the studied patients with MI ( $0.66 \pm 0.21$  m/s) than in the control ( $0.79 \pm 0.11$  m/s). This difference was found statistically significant ( $p < 0.05$ ).

- **The A-wave of conventional echo:**

The A-wave was found to be significantly higher in the studied patients with MI ( $0.72 \pm 0.19$  m/s) than in the control ( $0.59 \pm 0.09$  m/s). This difference was found statistically highly significant ( $p < 0.01$ ).

- **The E-wave deceleration time**

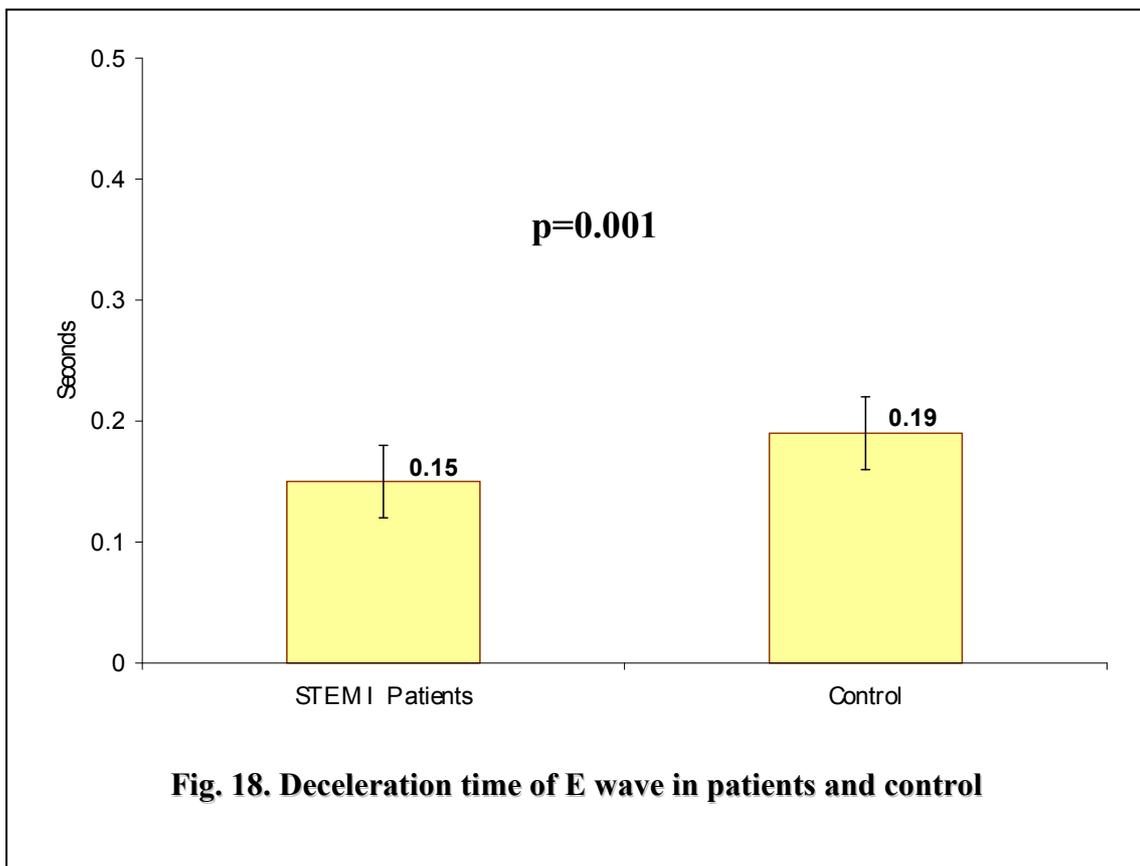
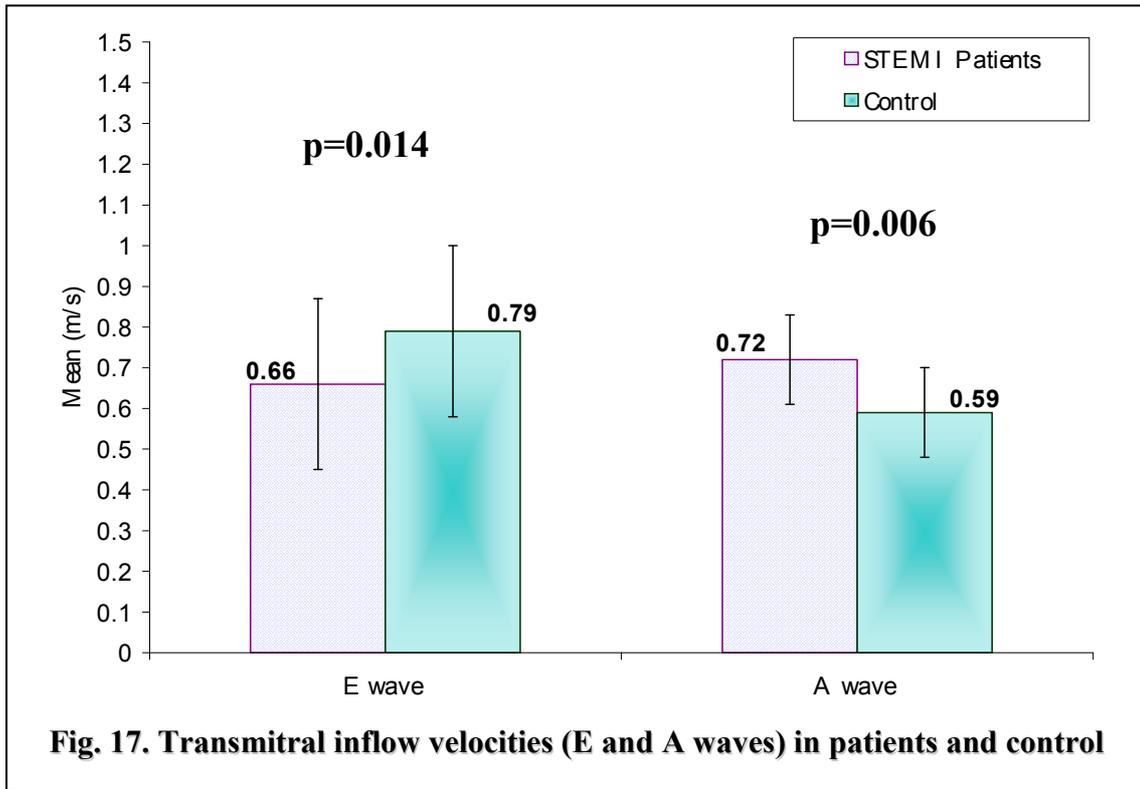
The E-wave deceleration time was significantly shorter in patients with MI ( $0.15 \pm 0.03$  sec.) compared to the control group ( $0.19 \pm 0.03$  sec.). This difference was found statistically highly significant ( $p < 0.01$ ).

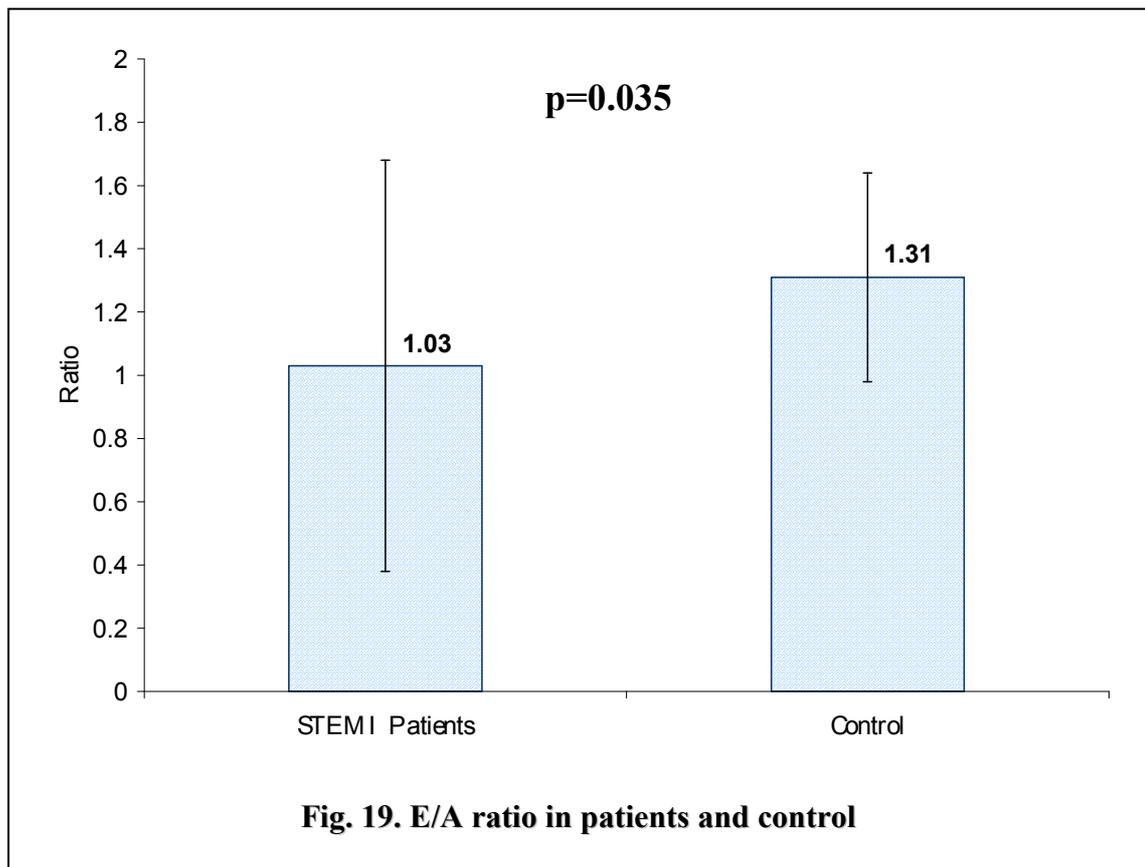
- **The E/A ratio of conventional echo:**

Patients with MI showed significant difference from the control group in that this ratio was above 1 ( $1.03 \pm 0.65$ ) while in the control group it was ( $1.31 \pm 0.33$ ). This difference was found statistically significant ( $p < 0.05$ ).

**Table 13. Comparison between patients with myocardial infarction and the control by transmitral inflow velocities**

<b>Transmitral inflow velocities</b>	<b>Patients (n= 40)</b>	<b>Control (n= 20)</b>	<b>p-value</b>
E wave (m/s):			
Min. - Max.	0.31 - 1.15	0.61 - 1.03	<b>0.014*</b>
Mean ± SD	0.66 ± 0.21	0.79 ± 0.11	
Median	0.64	0.77	
A wave (m/s):			
Min. - Max.	0.29 - 1.17	0.42 - 0.77	<b>0.006*</b>
Mean ± SD	0.72 ± 0.19	0.59 ± 0.09	
Median	0.71	0.59	
DT of E wave (sec):			
Min. - Max.	0.09 - 0.23	0.14 - 0.24	<b>0.001*</b>
Mean ± SD	0.15 ± 0.03	0.19 ± 0.03	
Median	0.15	0.18	
E/A ratio:			
Min. - Max.	0.35 - 3.53	0.71 - 2.44	<b>0.035*</b>
Mean ± SD	1.03 ± 0.65	1.31 ± 0.33	
Median	0.83	1.33	
<p>E: pulse wave Doppler early diastolic velocity                      A: pulse wave Doppler late diastolic velocity  DT: deceleration time  Student t- test for the difference between two means                      *Statistically significant</p>			



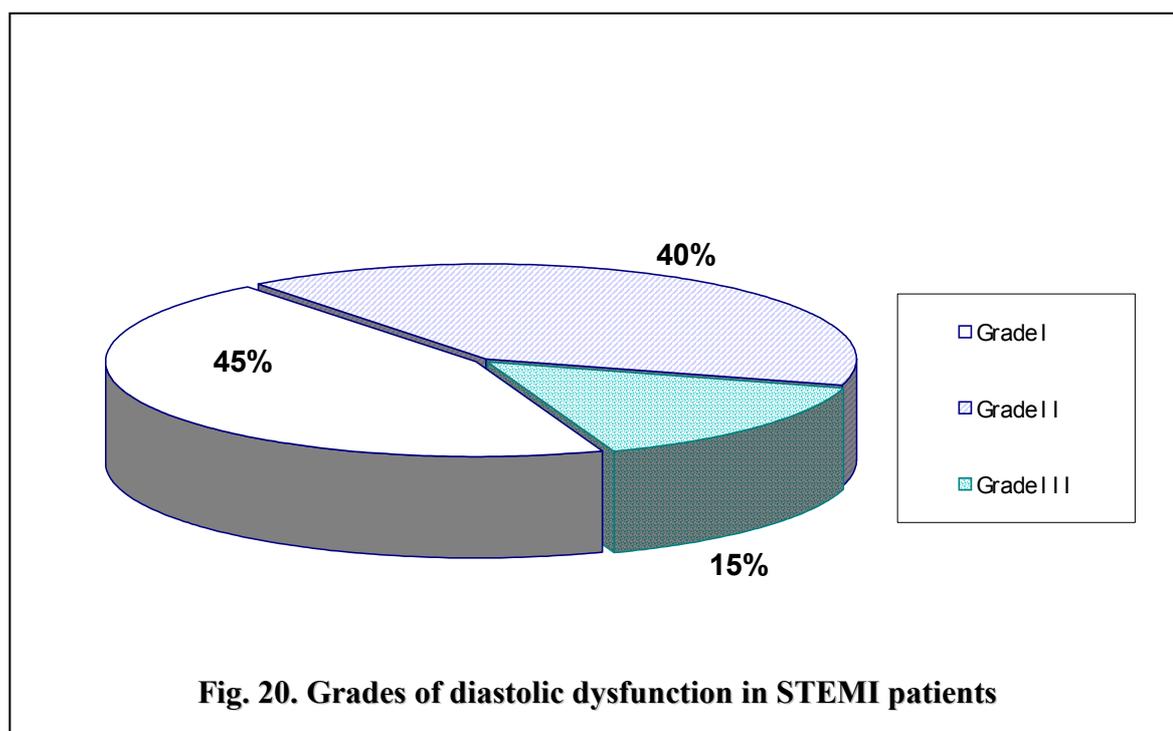


### Grades of diastolic dysfunction in the studied patients with MI: (Table 14 and Figure 20)

According to the American Heart Association grading of diastolic dysfunction, it was found that in the studied patients 18(45.0%) were of grade I; 16(40.0%) of grade II and 6(15.0%) of grade III.

**Table 14. Diastolic dysfunction grades of the studied patients**

Diastolic dysfunctions	Patients (n= 40)	
	№	%
Grade I	18	45.0
Grade II	16	40.0
Grade III	6	15.0



**Tissue Doppler imaging: (Table 15 and Figures 21-25)**

Pulse wave tissue Doppler study at the mitral annulus showed:

**- Sa wave (Sa):**

The value of the Sa wave of the TDI was significantly lower in the patients group ( $0.067 \pm 0.015$  m/s) when compared to the control group ( $0.098 \pm 0.019$  m/s), with  $p:0.0001$ .

**- Ea wave (Ea):**

The Ea wave of the mitral annulus in patients group ( $0.069 \pm 0.021$  m/s) was lower than in the control group ( $0.136 \pm 0.042$  m/s). This difference was statistically highly significant ( $p<0.01$ ).

**- Aa wave (Aa):**

The Aa wave of the mitral annulus was lower in patients group ( $0.093 \pm 0.02$  m/s) than in the control group ( $0.095 \pm 0.024$  m/s). This difference was not found statistically significant ( $p>0.05$ ).

**- Ea/Aa ratio:**

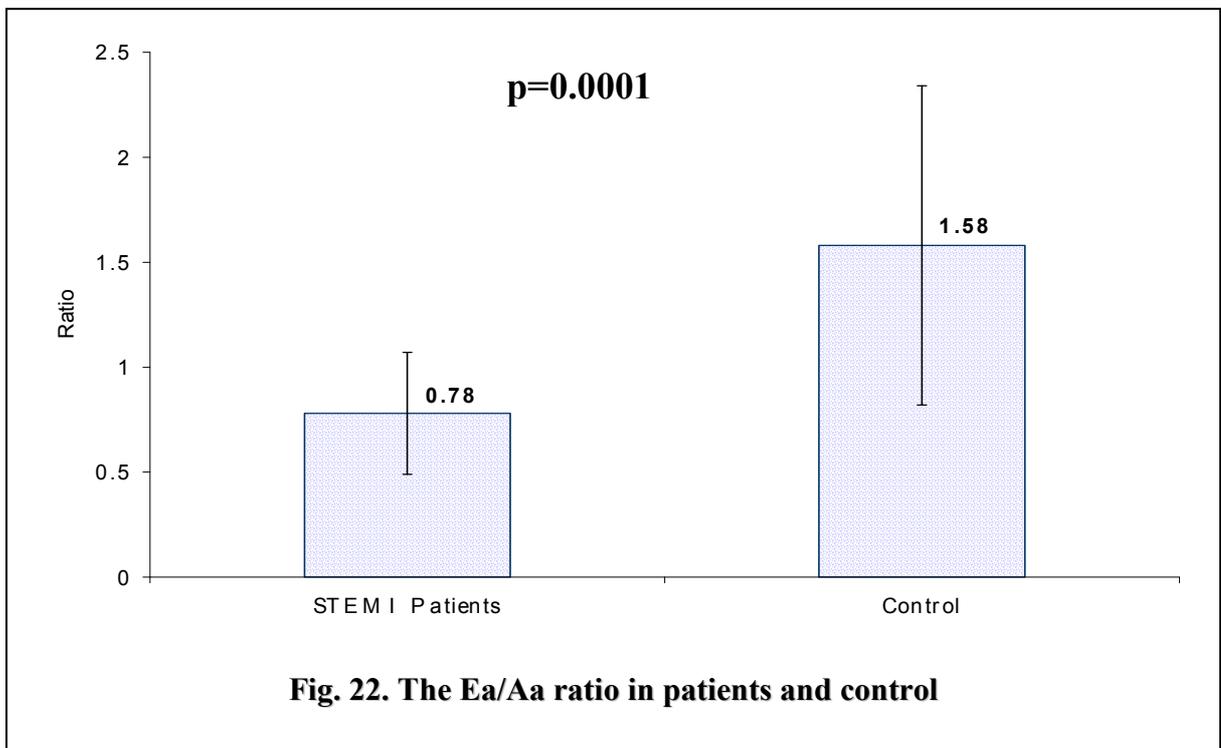
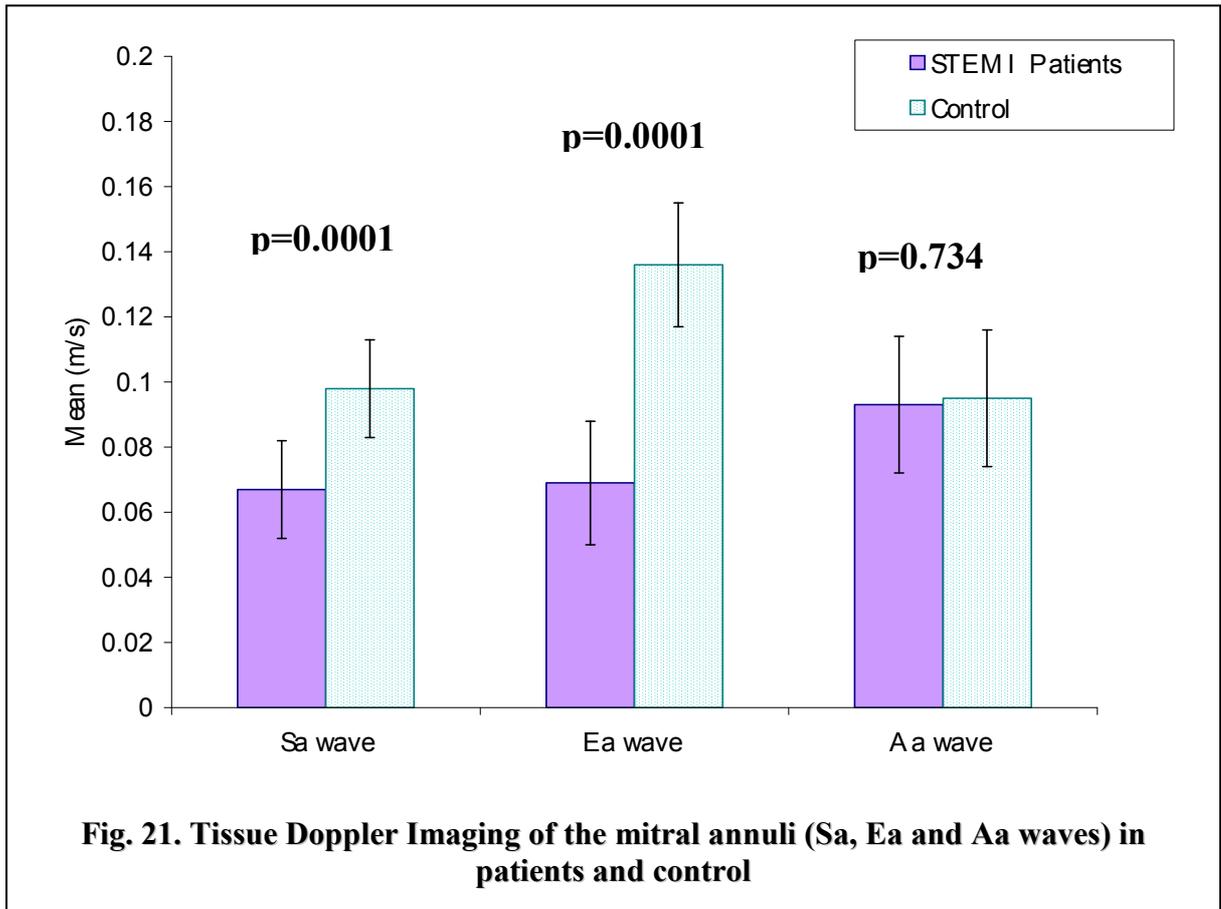
The Ea wave and Aa wave were divided to obtain Ea/Aa ratio. The patients group showed significant lower value ( $0.78 \pm 0.29$ ) than in the control group ( $1.58 \pm 0.76$ ). This difference was statistically highly significant ( $p<0.01$ ).

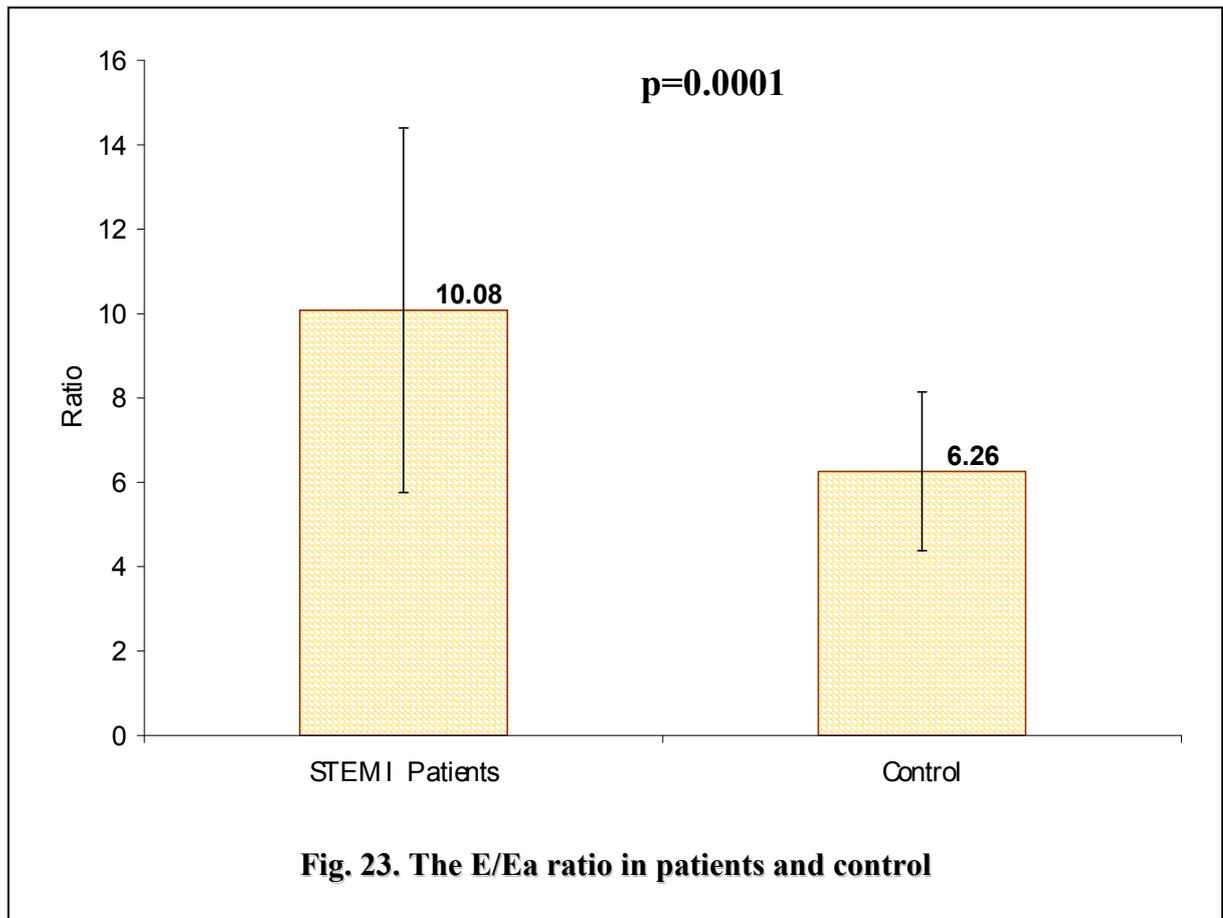
**- E/Ea ratio:**

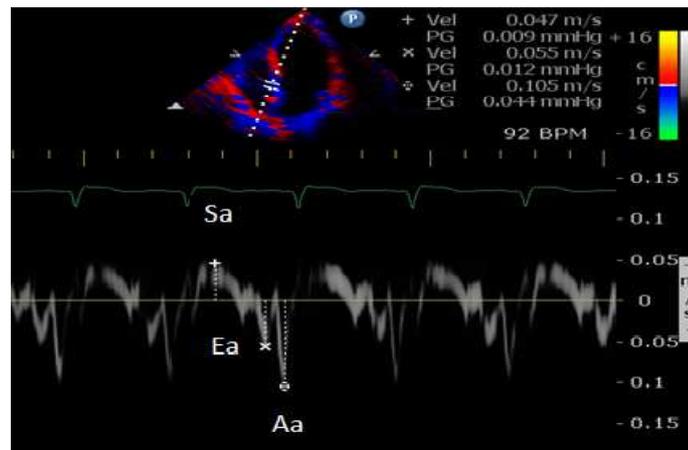
The E wave of transmitral inflow velocity and the Ea wave were divided to obtain E/Ea ratio. The patients group showed significant higher value ( $10.08 \pm 4.32$ ) than in the control group ( $6.26 \pm 1.88$ ). This difference was statistically highly significant ( $p<0.01$ ).

**Table 15. Comparison between patients with myocardial infarction and the control according to Tissue Doppler Imaging of the mitral annuli**

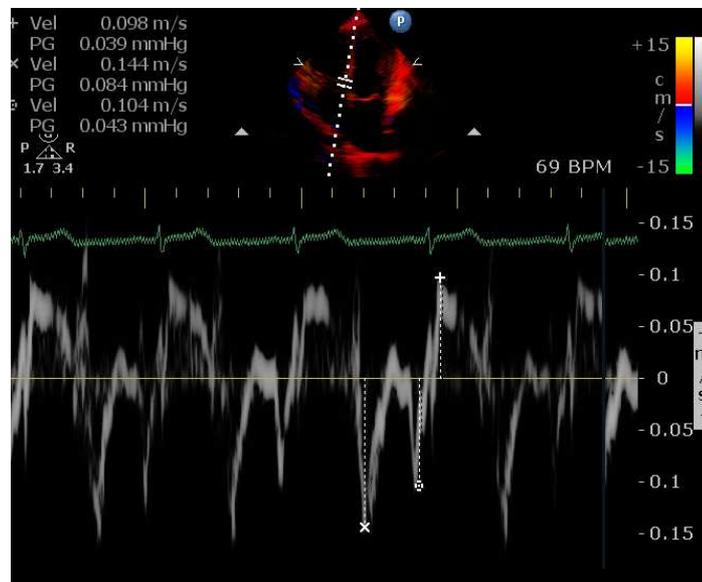
Tissue Doppler Imaging	Patients (n= 40)	Control (n= 20)	p-value
Sa wave (m/s):			
Min. - Max.	0.043-0.104	0.073- 0.147	<b>0.0001*</b>
Mean $\pm$ SD	0.067 $\pm$ 0.015	0.098 $\pm$ 0.019	
Median	0.067	0.097	
Ea wave (m/s):			
Min. - Max.	0.028 - 0.137	0.073 - 0.242	<b>0.0001*</b>
Mean $\pm$ SD	0.069 $\pm$ 0.021	0.136 $\pm$ 0.042	
Median	0.066	0.132	
Aa wave (m/s):			
Min. - Max.	0.057 - 0.141	0.059 - 0.155	0.734
Mean $\pm$ SD	0.093 $\pm$ 0.02	0.095 $\pm$ 0.024	
Median	0.089	0.094	
Ea/Aa ratio:			
Min. - Max.	0.37 - 1.35	0.47 - 3.53	<b>0.0001*</b>
Mean $\pm$ SD	0.78 $\pm$ 0.29	1.58 $\pm$ 0.76	
Median	0.69	1.43	
E/Ea ratio:			
Min. - Max.	5.15 - 27.38	3.52 - 10.27	<b>0.0001*</b>
Mean $\pm$ SD	10.08 $\pm$ 4.32	6.26 $\pm$ 1.88	
Median	9.26	6.05	
Sa: systolic velocity                      Ea: early diastolic tissue velocity                      Aa: late diastolic tissue velocity			
E: pulse wave Doppler early diastolic velocity			
Student t- test for the difference between two means		*Statistically significant	







**Fig. 24. Pulsed wave TDI of the septal mitral annulus of patient No.19 showing reduced systolic (Sa) and early diastolic (Ea) velocities, increased late diastolic velocity (Aa)**



**Fig. 25. Pulsed wave TDI of the septal mitral annulus of control No.6 showing normal systolic (Sa) and early diastolic (Ea) velocities, normal late diastolic velocity (Aa)**

**Left atrial functions: (Table 16 and Figures 26-31)**

Among the conventional echo measurements, the followings were measured:

**- Left atrial diameter:**

The left atrial diameter in patients group was significantly higher ( $4.11 \pm 0.58$  cm) than in the control group ( $3.52 \pm 0.44$  cm). This difference was found statistically highly significant ( $p < 0.01$ ).

**- Left atrial maximum volume (LAV max.):**

The LAV max. in patients group was significantly higher ( $57.57 \pm 27.06$  ml) than in the control group ( $37.74 \pm 16.84$  ml). This difference was found statistically highly significant ( $p < 0.01$ ).

When the LAV max. was indexed to the BSA, still there was higher mean in patients ( $30.15 \pm 14.45$  ml/m<sup>2</sup>) than in the control ( $20.07 \pm 9.04$  ml/m<sup>2</sup>), with significant statistical difference ( $p < 0.01$ ).

**- Left atrial minimum volume (LAV min.):**

The LAV min. in patients group was significantly higher ( $30.95 \pm 17.99$  ml) than in the control group ( $14.64 \pm 7.54$  ml). This difference was found statistically highly significant ( $p < 0.01$ ).

Even when the LAV min. was indexed to the BSA, still there was higher mean in patients ( $16.23 \pm 9.56$  ml/m<sup>2</sup>) than in the control ( $7.75 \pm 4.02$  ml/m<sup>2</sup>), with significant statistical difference ( $p < 0.01$ ).

**- Left atrial reservoir volume (LAV res.):**

The LAV res. in patients group was significantly higher ( $28.94 \pm 9.61$  ml) than in the control group ( $21.02 \pm 7.36$  ml). This difference was found statistically highly significant ( $p < 0.01$ ).

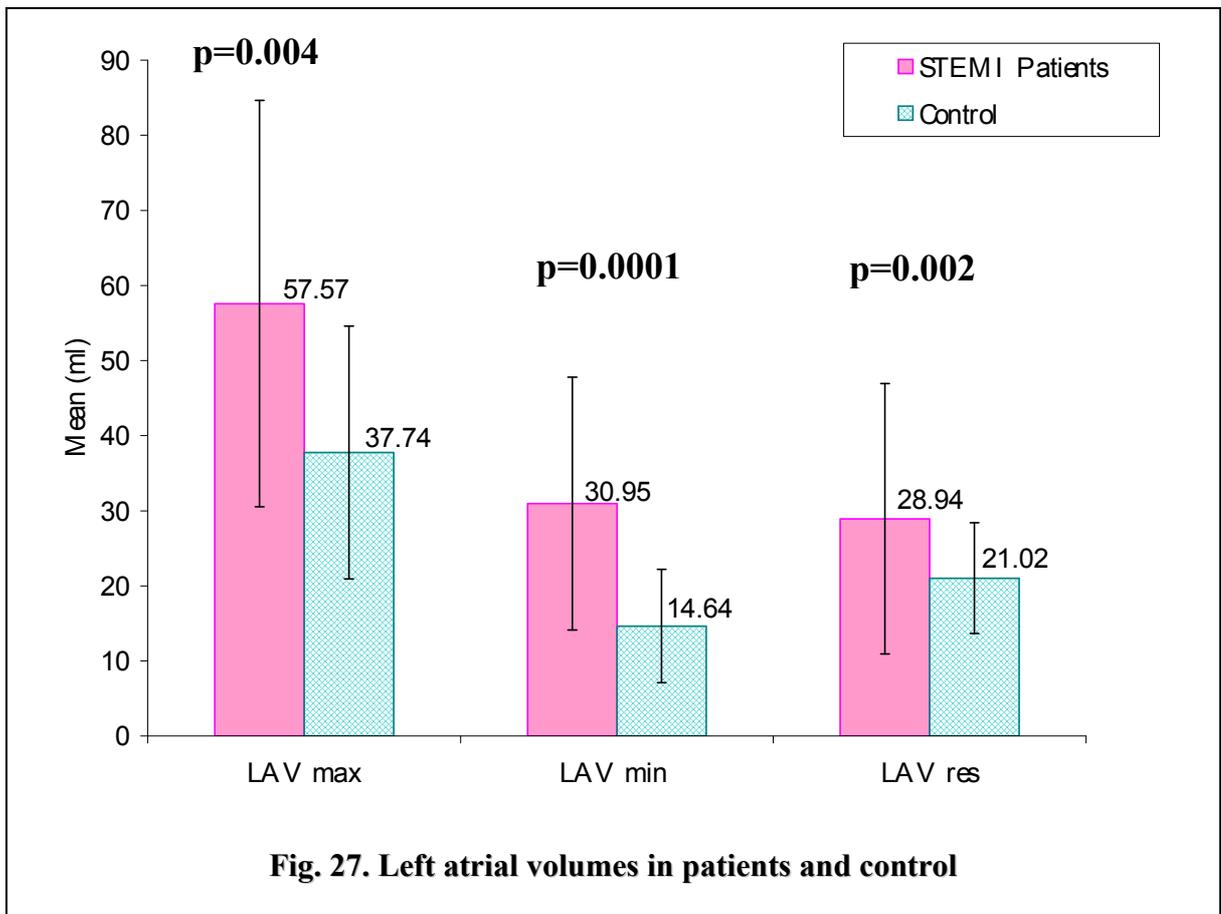
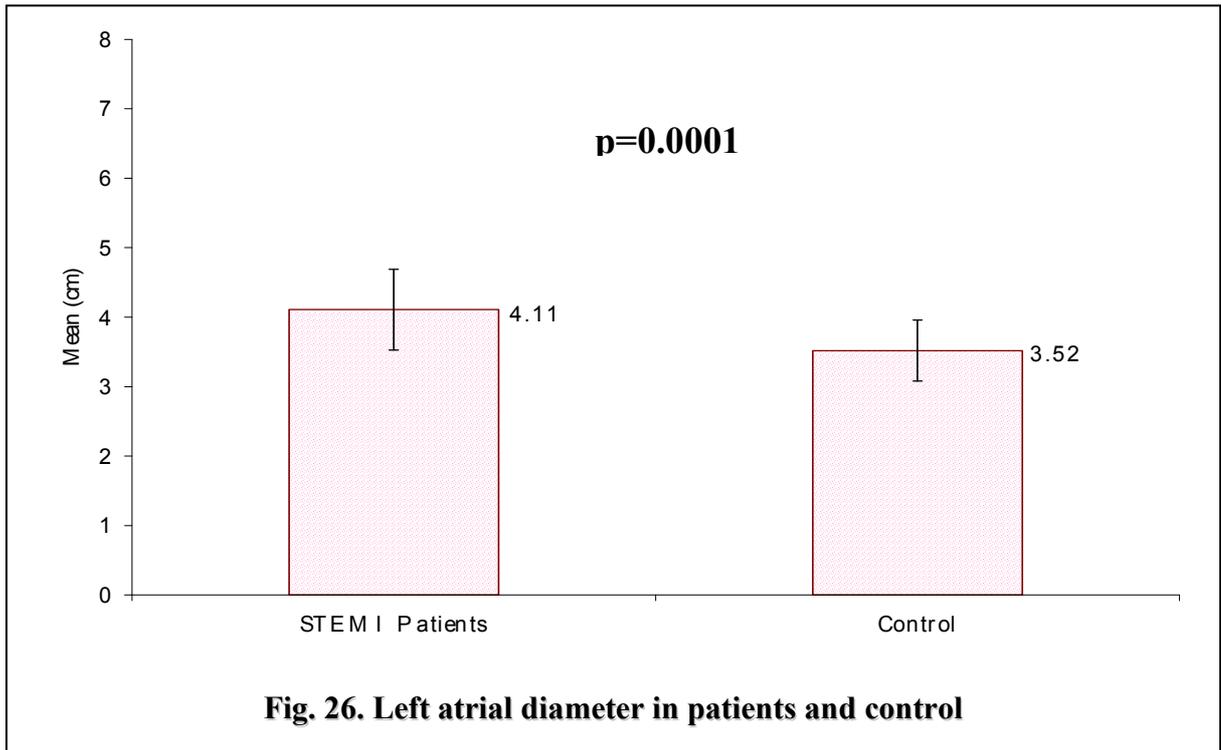
Even when the LAV res. was indexed to the BSA, still there was higher mean in patients ( $16.56 \pm 8.05$  ml/m<sup>2</sup>) than in the control ( $12.32 \pm 6.12$  ml/m<sup>2</sup>), with significant statistical difference ( $p < 0.05$ ).

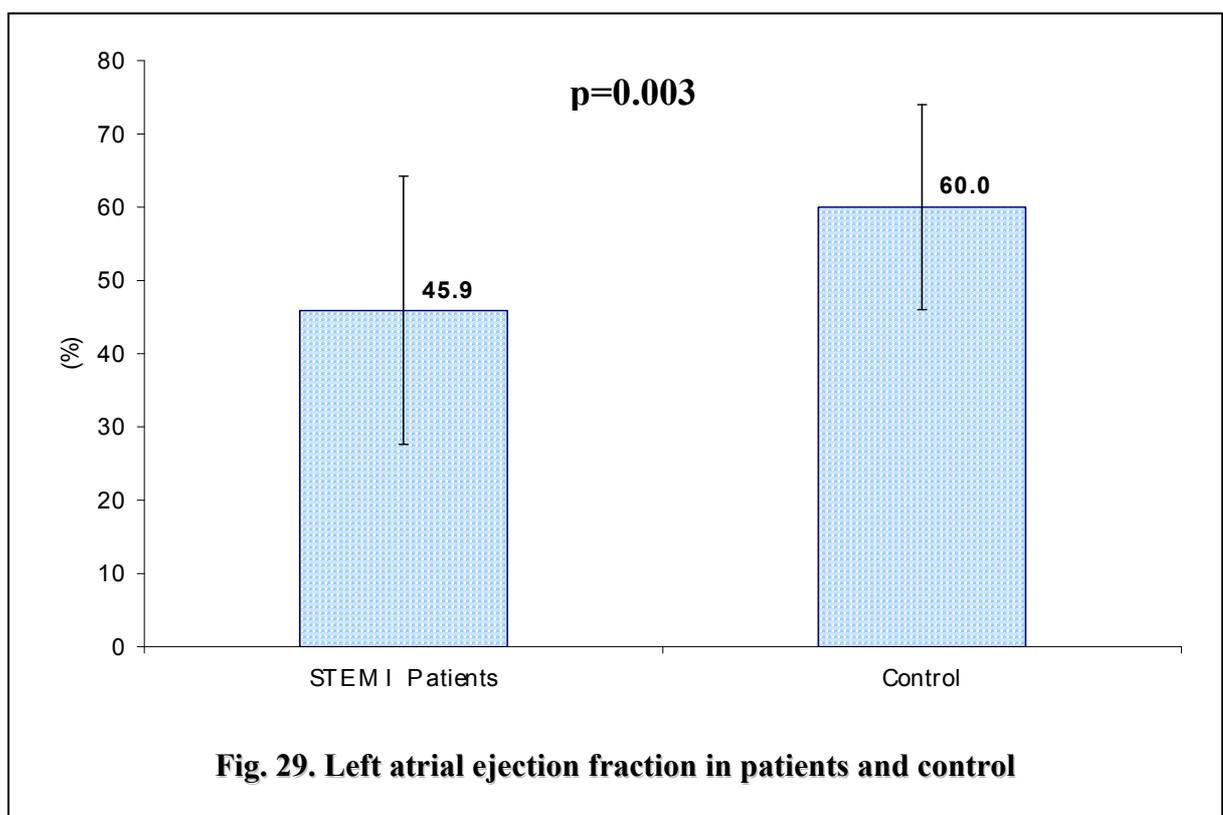
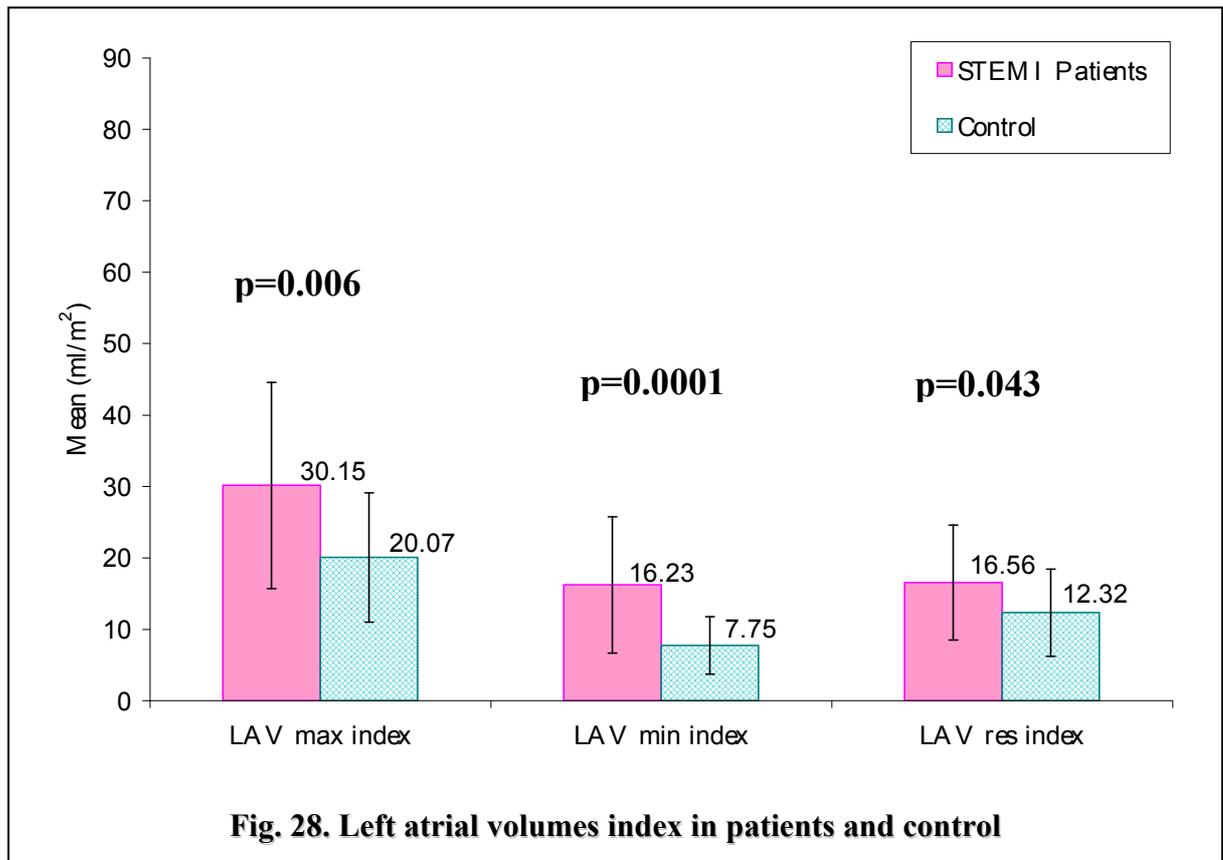
**- Left atrial ejection fraction (LAEF):**

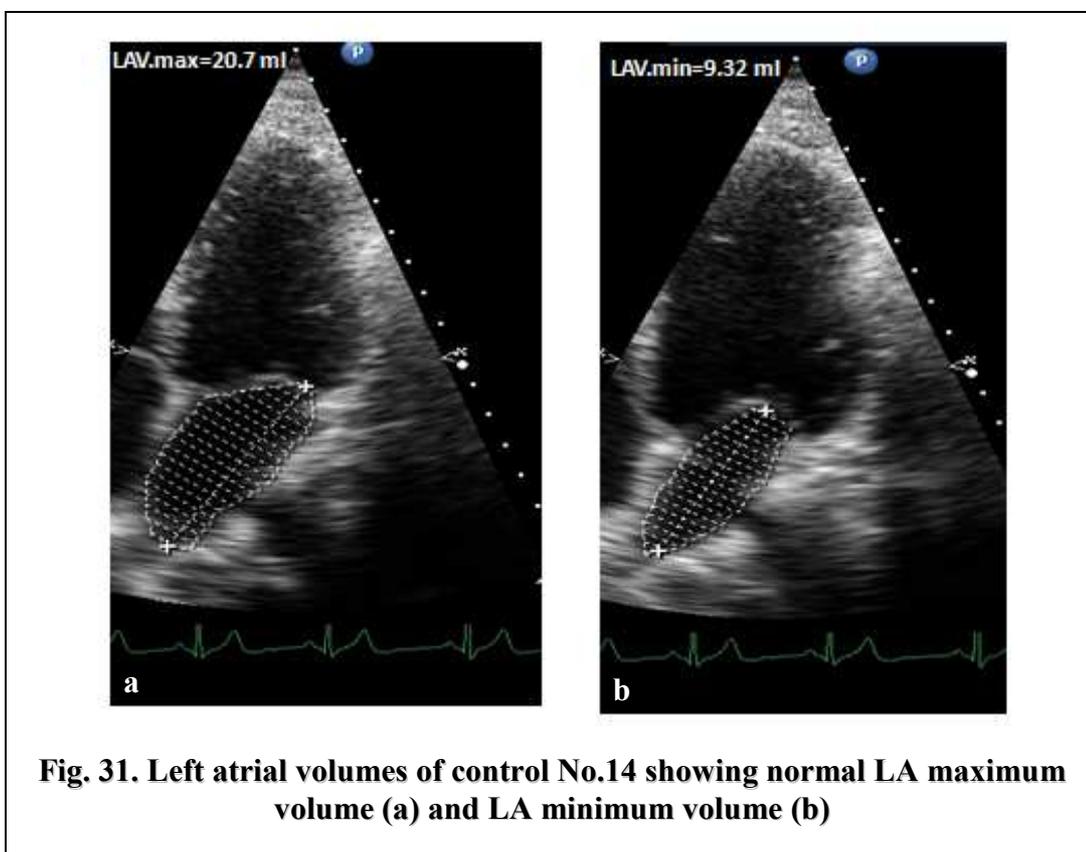
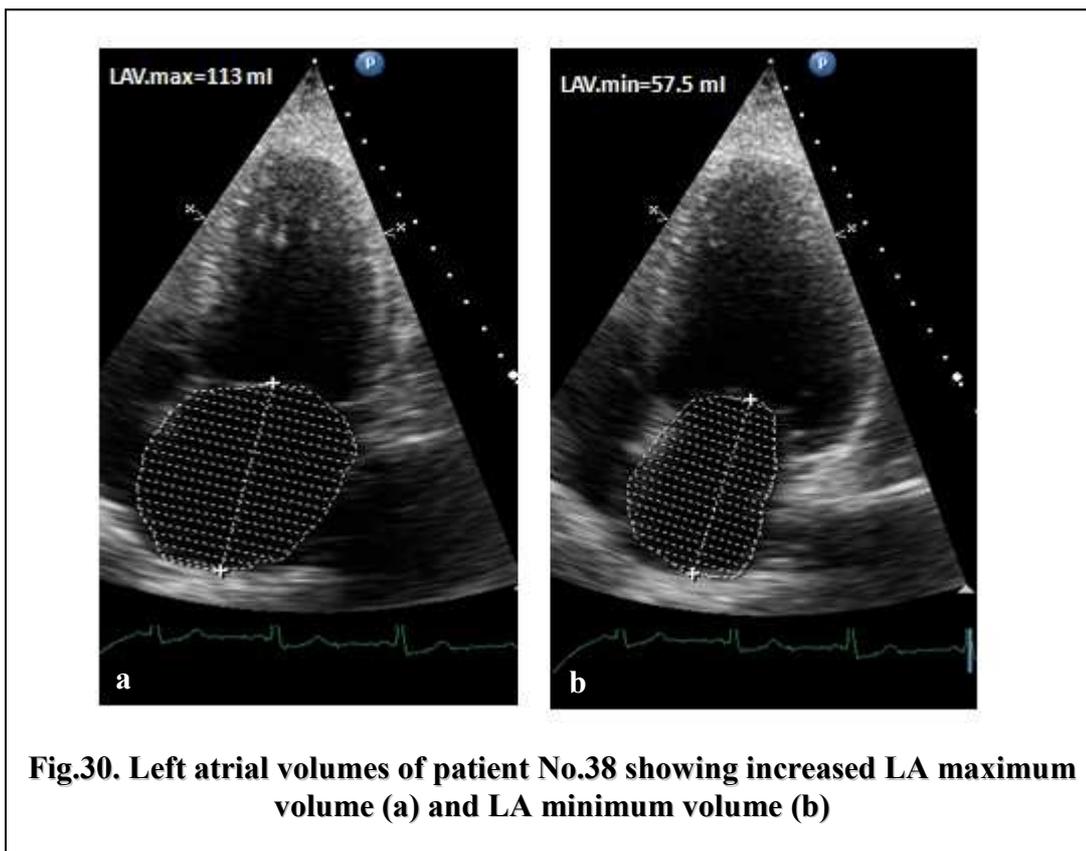
The LAEF in patients group was significantly lower ( $45.9 \pm 18.3$  %) than in the control group ( $60 \pm 14$  %). This difference was found statistically highly significant ( $p < 0.01$ ).

**Table 16. Comparison between patients with myocardial infarction and the control according to left atrial functions**

Left atrial functions	Patients (n= 40)	Control (n= 20)	p-value
Left atrial diameter (cm) :			
Min. - Max.	2.75 – 5.10	2.86 – 4.33	<b>0.0001*</b>
Mean ± SD	4.11 ± 0.58	3.52 ± 0.44	
Median	4.20	3.45	
LAV max (ml):			
Min. - Max.	19.70 - 148.0	16.50 - 67.30	<b>0.004*</b>
Mean ± SD	57.57 ± 27.06	37.74 ± 16.84	
Median	56.8	33.6	
LAV max index (ml/m <sup>2</sup> ):			
Min. - Max.	10.59 – 80.0	8.51 - 36.98	<b>0.006*</b>
Mean ± SD	30.15 ± 14.45	20.07 ± 9.04	
Median	29.9	17.28	
LAV min (ml):			
Min. - Max.	7.51 - 100.0	3.82 - 29.60	<b>0.0001*</b>
Mean ± SD	30.95 ± 17.99	14.64 ± 7.54	
Median	27.35	21.95	
LAV min index (ml/m <sup>2</sup> ):			
Min. - Max.	4.04 - 53.19	2.22 - 16.44	<b>0.0001*</b>
Mean ± SD	16.23 ± 9.56	7.75 ± 4.02	
Median	14.64	7.38	
LAV res (ml):			
Min. - Max.	1.20 – 84.40	1.40 – 45.30	<b>0.002*</b>
Mean ± SD	28.94 ± 9.61	21.02 ± 7.36	
Median	27.6	22.3	
LAV res index (ml/m <sup>2</sup> )			
Min. - Max.	0.64 - 45.62	0.72 - 24.89	<b>0.043*</b>
Mean ± SD	16.56 ± 8.05	12.32 ± 6.12	
Median	14.2	11.6	
LAEF (%):			
Min. - Max.	2 – 72	8 – 85	<b>0.003*</b>
Mean ± SD	45.9 ± 18.3	60 ± 14	
Median	50.5	62.6	
LAV max: Maximum left atrial volume		LAV min: Minimum left atrial volume	
LAV res: left atrial reservoir volume		LAEF: left atrial ejection fraction	
Student t- test for the difference between two means		*Statistically significant	







**Tissue Doppler derived left atrial strain:****Left atrial strain of the anterior wall: (Table 17 and Figures 32,33,40-43)**

The left atrial peak systolic strain in the apical, mid, and basal segments of patients were lower than in the control ( $11.02 \pm 6.85\%$  vs.  $24.81 \pm 15.96\%$ ;  $10.35 \pm 6.27\%$  vs.  $30.70 \pm 13.14\%$ ;  $7.77 \pm 5.91\%$  vs.  $11.69 \pm 7.11\%$  respectively). These differences were found statistically significant ( $p=0.0001$ ,  $p=0.0001$ ,  $p=0.028$  respectively).

Even the mean left atrial peak systolic strain of the anterior wall was significantly lower in patients ( $9.71 \pm 3.89\%$ ) than in the control ( $22.40 \pm 7.85\%$ ) and this was found statistically significant ( $p < 0.01$ ).

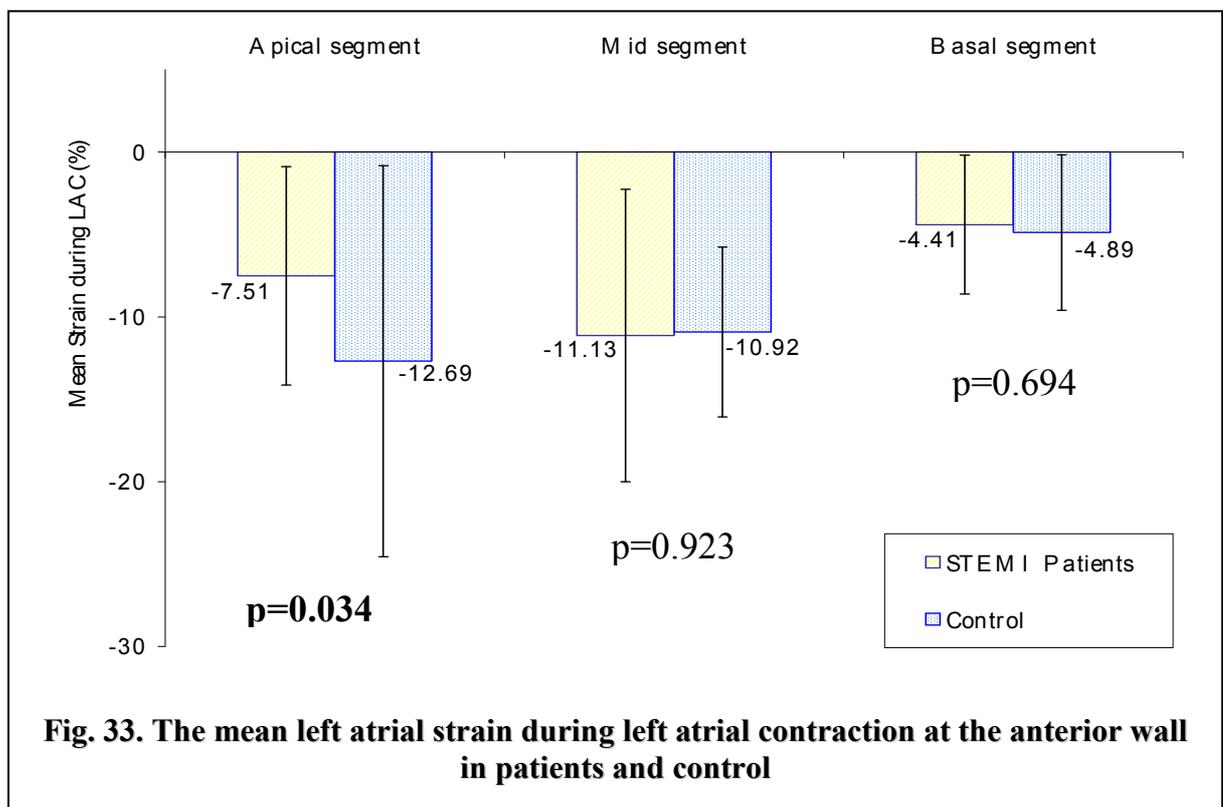
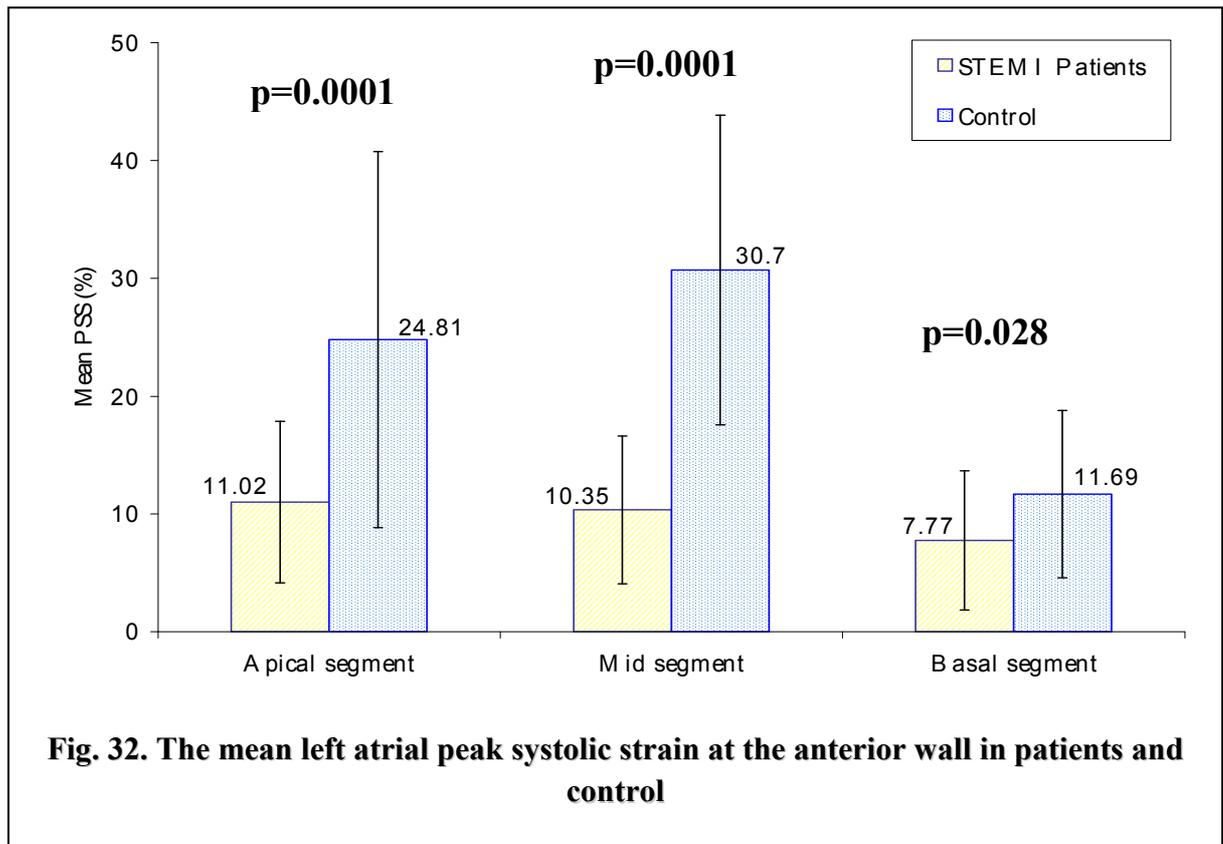
The left atrial strain during left atrial contraction (LAC) in the apical and basal segments of patients were lower than in the control ( $-7.51 \pm 6.63\%$  vs.  $-12.69 \pm 11.86\%$ ;  $-4.41 \pm 4.22\%$  vs.  $-4.89 \pm 4.72\%$  respectively). However, the difference was found statistically significant for apical ( $p=0.034$ ) and insignificant for basal ( $p=0.694$ ) segments.

For the mid segment; the left atrial strain during LAC was higher among patients than in the control ( $-11.13 \pm 8.87\%$  vs.  $-10.92 \pm 5.15\%$ ) with insignificant difference ( $p=0.923$ ).

The mean of the left atrial strain during LAC for the anterior wall was lower in patients ( $-6.82 \pm 4.78\%$ ) than in the control ( $-9.50 \pm 6.84\%$ ) and this was found statistically insignificant ( $p=0.082$ ).

**Table 17. Comparison between patients with myocardial infarction and the control according to atrial strain at the anterior wall**

Anterior wall	Patients (n= 40)	Control (n= 20)	p-value
<b>- Apical segment:</b>			
PS Strain (%):			<b>0.0001*</b>
Min. - Max.	0.60 - 25.34	1.49 - 68.17	
Mean ± SD	11.02 ± 6.85	24.81 ± 15.96	
Median	10.24	20.61	
Strain during LAC (%):			<b>0.034*</b>
Min. - Max.	- 0.03 - -25.54	- 0.61 - - 42.04	
Mean ± SD	- 7.51 ± 6.63	- 12.69 ± 11.86	
Median	- 5.02	- 8.87	
<b>- Mid segment:</b>			
PS Strain (%):			<b>0.0001*</b>
Min. - Max.	0.44 - 30.36	10.05 -59.53	
Mean ± SD	10.35 ± 6.27	30.70 ± 13.14	
Median	9.07	30.78	
Strain during LAC (%):			0.923
Min. - Max.	- 0.52 - -33.85	-0.92 - -54.26	
Mean ± SD	-11.13 ± 8.87	-10.92 ± 5.15	
Median	- 6.07	- 6.43	
<b>-Basal segment</b>			
PS Strain (%):			<b>0.028*</b>
Min. - Max.	1.07 - 25.98	1.43 - 27.82	
Mean ± SD	7.77 ± 5.91	11.69 ± 7.11	
Median	5.50	11.84	
Strain during LAC (%):			0.694
Min. - Max.	-0.19 - -18.14	-0.38 - -16.44	
Mean ± SD	-4.41 ± 4.22	-4.89 ± 4.72	
Median	-3.49	-3.21	
<b>Mean anterior wall PS strain (%):</b>			<b>0.0001*</b>
Min. - Max.	1.31 – 15.96	12.19 – 41.55	
Mean ± SD	9.71 ± 3.89	22.40 ± 7.85	
Median	10.09	21.51	
<b>Mean anterior wall strain during LAC (%)</b>			0.082
Min. - Max.	-1.22 – -18.36	-1.26 – -22.84	
Mean ± SD	-6.82 ± 4.78	-9.50 ± 6.84	
Median	-4.91	-7.38	
PS: peak systolic			
LAC: left atrial contraction			
Student t- test for the difference between two means			
*Statistically significant			



**Left atrial strain of the inferior wall: (Table 18 and Figures 34,35, 40-43)**

The left atrial peak systolic strain in the apical, mid, and basal segments of patients were lower than in the control (17.69±8.69% vs. 28.13±8.97%; 13.83±7.48% vs. 21.39±8.48%; 6.96±4.09% vs. 14.61±8.59% respectively). These differences were found statistically significant (p=0.0001, p=0.001, p=0.0001 respectively).

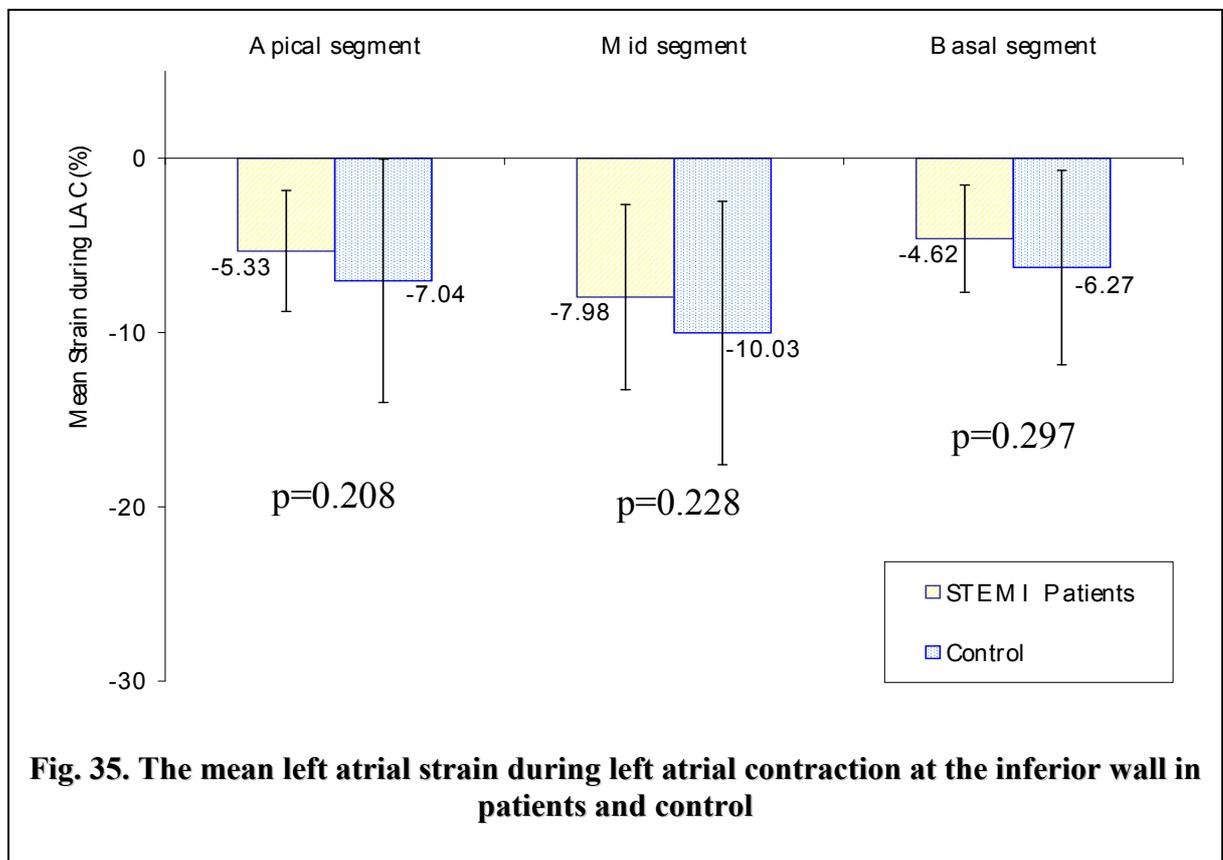
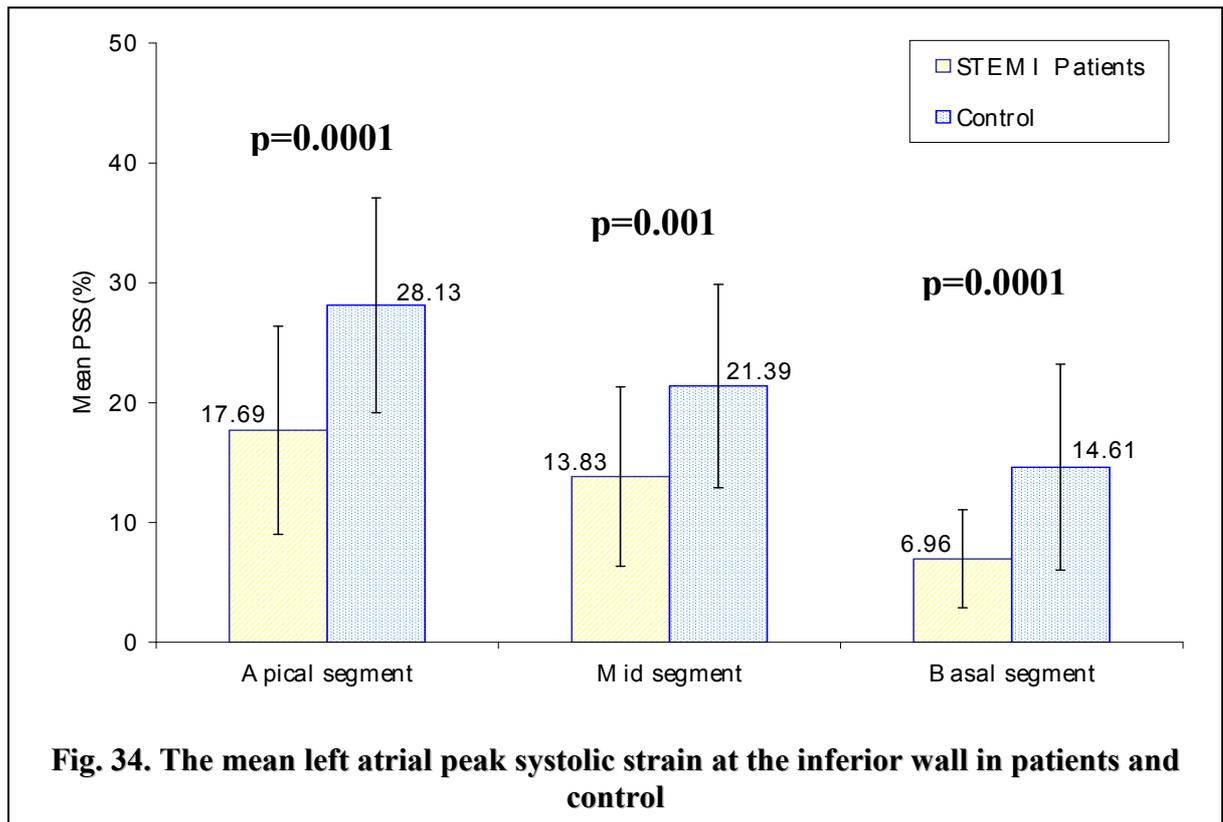
Even the mean left atrial peak systolic strain of the inferior wall was significantly lower in patients (12.83 ± 5.77%) than in the control (21.38 ± 4.04%) and this was found statistically significant (p = 0.0001).

The left atrial strain during LACs of the inferior wall in the apical, mid and basal segments of patients were lower than in the control (-5.33±3.47% vs. -7.04±6.97%; -7.98±5.31% vs. -10.03±7.56%; -4.62±3.07% vs. -6.27±5.58% respectively). However, these difference were found statistically insignificant (p=0.208, p=0.228, p=0.297 respectively).

The mean of the left atrial strain during LAC for the inferior wall was lower in patients (-5.83 ± 3.92%) than in the control (-7.78 ± 3.74%) and this was found statistically insignificant (p=0.070).

**Table 18. Comparison between patients with myocardial infarction and the control according to atrial strain at the inferior wall**

Inferior wall	Patients (n= 40)	Control (n= 20)	p-value
<b>- Apical segment:</b>			
PS Strain (%):			<b>0.0001*</b>
Min. - Max.	2.06 - 49.02	11.37- 44.22	
Mean ± SD	17.69 ± 8.69	28.13 ± 8.97	
Median	15.80	28.92	
Strain during LAC (%):			0.208
Min. - Max.	-0.23 - -24.21	-0.06 - -24.37	
Mean ± SD	-5.33 ± 3.47	-7.04 ± 6.97	
Median	-4.25	-4.71	
<b>- Mid segment:</b>			
PS Strain (%):			<b>0.001*</b>
Min. - Max.	0.29 - 30.92	5.38 - 34.23	
Mean ± SD	13.83 ± 7.48	21.39 ± 8.48	
Median	14.02	23.09	
Strain during LAC (%):			0.228
Min. - Max.	-0.17 - -38.63	-0.54 - -28.63	
Mean ± SD	-7.98 ± 5.31	-10.03 ± 7.56	
Median	-5.43	-8.82	
<b>-Basal segment</b>			
PS Strain (%):			<b>0.0001*</b>
Min. - Max.	0.14 - 23.31	2.82 - 34.75	
Mean ± SD	6.96 ± 4.09	14.61 ± 8.59	
Median	4.29	13.59	
Strain during LAC (%):			0.297
Min. - Max.	-0.15 - -12.54	-0.21 - -22.36	
Mean ± SD	-4.62 ± 3.07	-6.27 ± 5.58	
Median	-4.18	-4.46	
<b>Mean inferior wall PS strain (%):</b>			<b>0.0001*</b>
Min. - Max.	1.90 – 26.12	13.75 – 28.45	
Mean ± SD	12.83 ± 5.77	21.38 ± 4.04	
Median	12.01	21.81	
<b>Mean inferior wall strain during LAC (%)</b>			0.070
Min. - Max.	-2.02 – -20.76	-0.84 – -17.37	
Mean ± SD	-5.83 ± 3.92	-7.78 ± 3.74	
Median	-4.38	-7.89	
PS: peak systolic		LAC: left atrial contraction	
Student t- test for the difference between two means		*Statistically significant	



**Left atrial strain of the lateral wall: (Table 19 and Figures 36,37, 40-43)**

The left atrial peak systolic strain in the apical, mid, and basal segments of patients were lower than in the control ( $9.84\pm 7.95\%$  vs.  $34.74\pm 17.04\%$ ;  $14.14\pm 9.34\%$  vs.  $22.36\pm 10.57\%$ ;  $9.12\pm 5.11\%$  vs.  $12.33\pm 6.84\%$  respectively). These differences were found statistically significant ( $p=0.0001$ ,  $p=0.012$ ,  $p=0.046$  respectively).

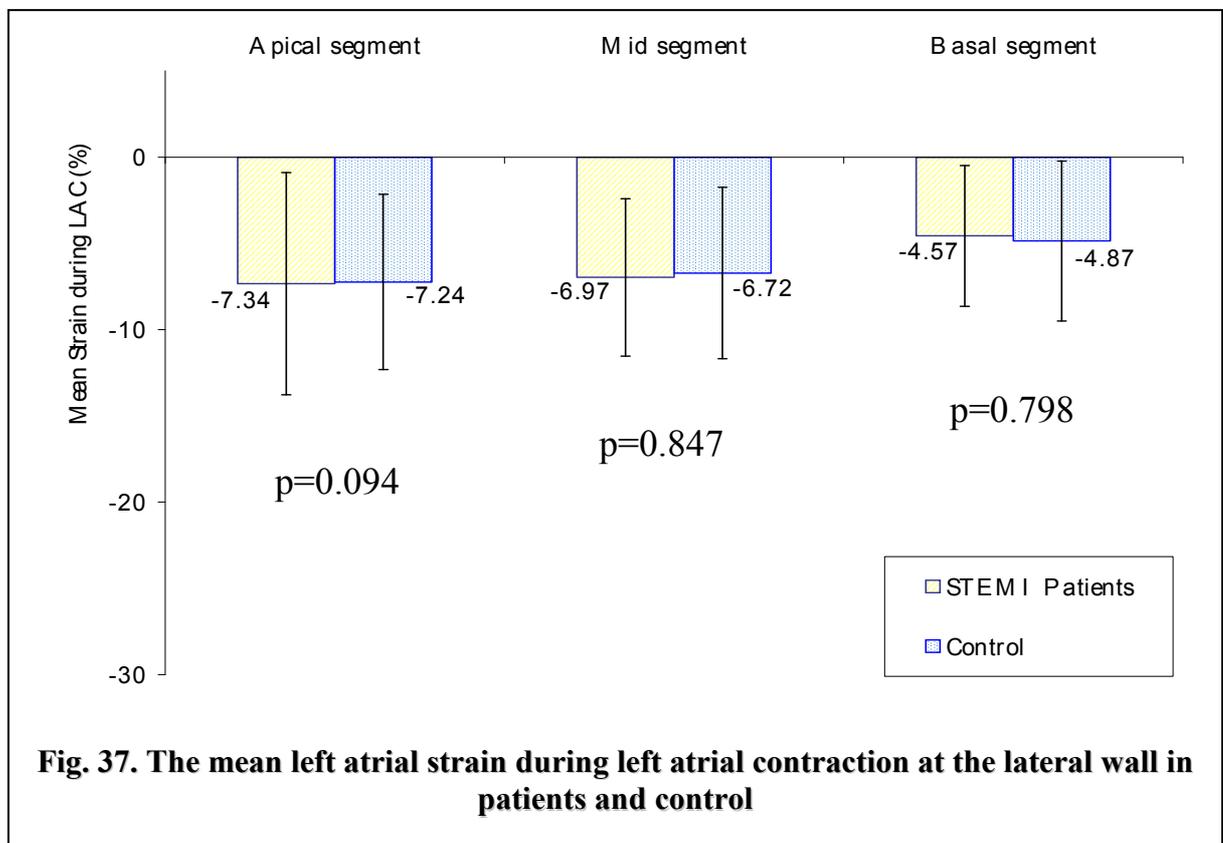
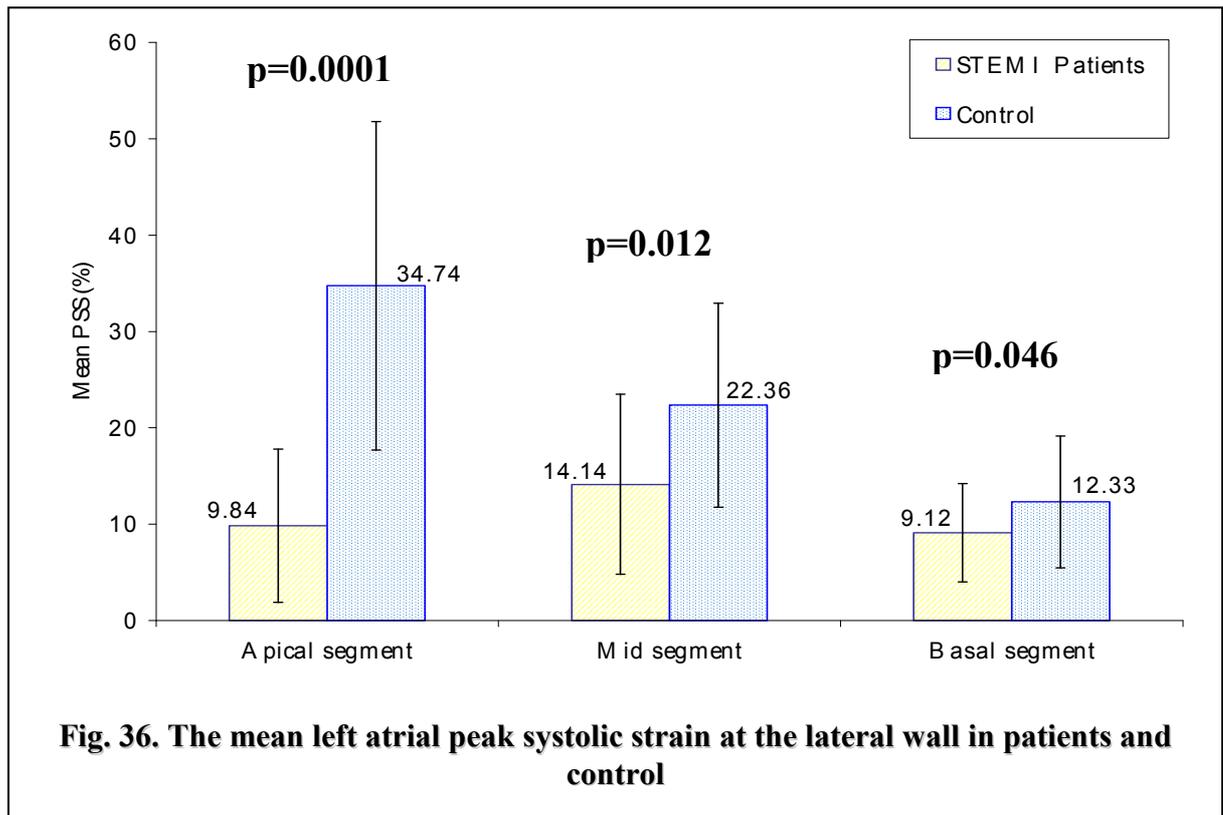
Even the mean left atrial peak systolic strain of the lateral wall was significantly lower in patients ( $11.03 \pm 5.17 \%$ ) than in the control ( $23.15 \pm 6.95\%$ ) and this was found statistically significant ( $p = 0.0001$ ).

The left atrial strain during LACs of the lateral wall in the apical and mid segments of patients were slightly higher than in the control ( $-7.34\pm 6.43\%$  vs.  $-7.24\pm 5.09\%$ ;  $-6.97\pm 4.56\%$  vs.  $-6.72\pm 4.97\%$ ) respectively, and slightly lower for basal segment ( $-4.57\pm 4.08\%$  vs.  $-4.87\pm 4.63\%$ ). However, these difference were found statistically insignificant ( $p=0.094$ ,  $p=0.847$ ,  $p= 0.798$  respectively).

The mean of the left atrial strain during LAC for the lateral wall was higher in patients ( $-6.19 \pm 3.99\%$ ) than in the control ( $-5.71 \pm 4.49\%$ ) and this was found statistically insignificant ( $p=0.673$ ).

**Table 19. Comparison between patients with myocardial infarction and the control according to atrial strain at the lateral wall**

Lateral wall	Patients (n= 40)	Control (n= 20)	p-value
<b>- Apical segment:</b>			
PS Strain (%):			<b>0.0001*</b>
Min. - Max.	0.94 - 35.60	14.50 - 76.51	
Mean ± SD	9.84 ± 7.95	34.74 ± 17.04	
Median	6.52	33.06	
Strain during LAC (%):			0.094
Min. - Max.	-0.12 - -24.10	-0.26 - -28.85	
Mean ± SD	-7.34 ± 6.43	-7.24 ± 5.09	
Median	-5.36	-1.78	
<b>- Mid segment:</b>			
PS Strain (%):			<b>0.012*</b>
Min. - Max.	0.02 - 38.58	8.78 - 41.13	
Mean ± SD	14.14 ± 9.34	22.36 ± 10.57	
Median	12.96	19.46	
Strain during LAC (%):			0.847
Min. - Max.	-0.18 - -33.18	-0.38 - -15.00	
Mean ± SD	-6.97 ± 4.56	-6.72 ± 4.97	
Median	-5.26	-5.41	
<b>-Basal segment</b>			
PS Strain (%):			<b>0.046*</b>
Min. - Max.	1.10 - 29.73	1.13 - 37.78	
Mean ± SD	9.12 ± 5.11	12.33 ± 6.84	
Median	7.70	10.77	
Strain during LAC (%):			0.798
Min. - Max.	-0.03 - -26.65	-0.03 - -22.19	
Mean ± SD	-4.57 ± 4.08	-4.87 ± 4.63	
Median	-2.41	-2.25	
<b>Mean lateral wall PS strain (%):</b>			<b>0.0001*</b>
Min. - Max.	1.62 – 23.73	13.04 – 41.20	
Mean ± SD	11.03 ± 5.17	23.15 ± 6.95	
Median	10.34	23.32	
<b>Mean lateral wall strain during LAC (%)</b>			0.673
Min. - Max.	-1.75 – -20.89	-0.54 – -19.07	
Mean ± SD	-6.19 ± 3.99	-5.71 ± 4.49	
Median	-5.55	-5.04	
PS: peak systolic			
Student t- test for the difference between two means		LAC: left atrial contraction	
		*Statistically significant	



**Left atrial strain of the septal wall: (Table 20 and Figures 38-43)**

The left atrial peak systolic strain in the apical, mid, and basal segments of patients were lower than in the control ( $12.69 \pm 7.22\%$  vs.  $21.13 \pm 9.72\%$ ;  $14.12 \pm 8.97\%$  vs.  $21.22 \pm 17.89\%$ ;  $12.74 \pm 9.87\%$  vs.  $26.04 \pm 14.64\%$  respectively). These differences were found statistically significant ( $p=0.0001$ ,  $p=0.044$ ,  $p=0.0001$  respectively).

Even the mean left atrial peak systolic strain of the septal wall was significantly lower in patients ( $13.18 \pm 5.68\%$ ) than in the control ( $22.79 \pm 6.09\%$ ) and this was found statistically significant ( $p = 0.0001$ ).

The left atrial strain during LACs of the septal wall in the apical, mid and basal segments of patients were lower than in the control ( $-4.95 \pm 3.97\%$  vs.  $-8.74 \pm 6.91\%$ ;  $-6.14 \pm 5.72\%$  vs.  $-12.53 \pm 9.01\%$ ;  $5.65 \pm 4.10\%$  vs.  $-6.45 \pm 5.63\%$  respectively). However, these difference were found statistically significant for apical and mid segments ( $p=0.009$ ,  $p=0.001$  respectively) and insignificant for basal segment ( $p=0.533$ ).

The mean of the left atrial strain during LAC for the septal wall was lower in patients ( $-5.57 \pm 3.56\%$ ) than in the control ( $-9.24 \pm 3.14\%$ ) and this was found statistically significant ( $p=0.0001$ ).

**Table 20. Comparison between patients with myocardial infarction and the control according to atrial strain at the septal wall**

Septal wall	Patients (n= 40)	Control (n= 20)	p-value
<b>- Apical segment:</b>			
PS Strain (%):			
Min. - Max.	1.41 - 30.08	10.70 - 45.94	<b>0.0001*</b>
Mean ± SD	12.69 ± 7.22	21.13 ± 9.72	
Median	11.66	19.77	
Strain during LAC (%):			
Min. - Max.	-0.06 - -30.06	-0.62 - -21.18	<b>0.009*</b>
Mean ± SD	-4.95 ± 3.97	-8.74 ± 6.91	
Median	-2.91	-6.03	
<b>- Mid segment:</b>			
PS Strain (%):			
Min. - Max.	1.60 - 36.85	6.99 - 78.78	<b>0.044*</b>
Mean ± SD	14.12 ± 8.97	21.22 ± 17.89	
Median	12.21	16.68	
Strain during LAC (%):			
Min. - Max.	-0.25 - -23.27	-3.08 - -41.81	<b>0.001*</b>
Mean ± SD	-6.14 ± 5.72	-12.53 ± 9.01	
Median	-4.07	-11.52	
<b>-Basal segment</b>			
PS Strain (%):			
Min. - Max.	0.08 - 38.09	2.02 - 55.79	<b>0.0001*</b>
Mean ± SD	12.74 ± 9.87	26.04 ± 14.64	
Median	11.02	30.61	
Strain during LAC (%):			
Min. - Max.	-0.11 - -31.37	-0.51 - -18.24	0.533
Mean ± SD	-5.65 ± 4.10	-6.45 ± 5.63	
Median	-4.37	-4.38	
<b>Mean septal wall PS strain (%):</b>			
Min. - Max.	4.01 - 25.79	13.88 - 41.07	<b>0.0001*</b>
Mean ± SD	13.18 ± 5.68	22.79 ± 6.09	
Median	11.81	22.77	
<b>Mean septal wall strain during LAC (%)</b>			
Min. - Max.	-1.07 - -15.40	-5.01 - -17.71	<b>0.0001*</b>
Mean ± SD	-5.57 ± 3.56	-9.24 ± 3.14	
Median	-4.15	-8.30	
PS: peak systolic		LAC: left atrial contraction	
Student t- test for the difference between two means		*Statistically significant	

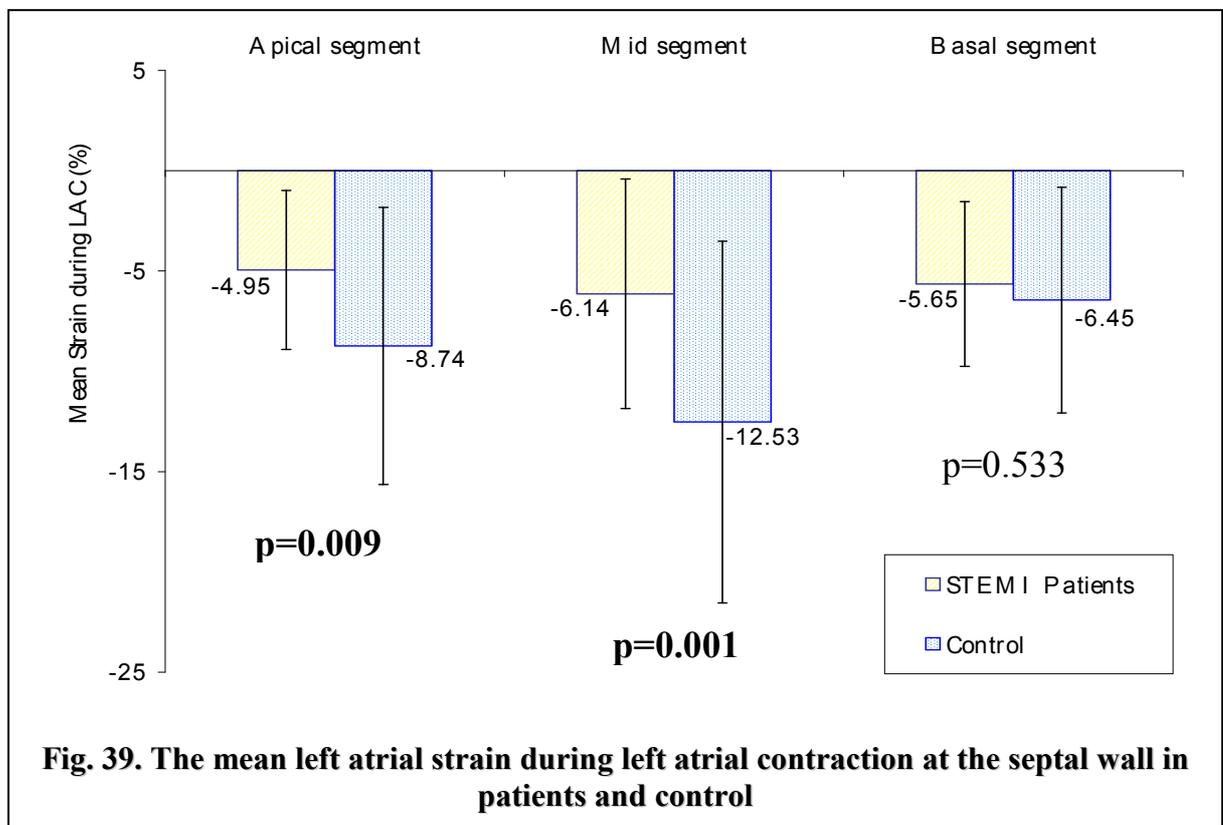
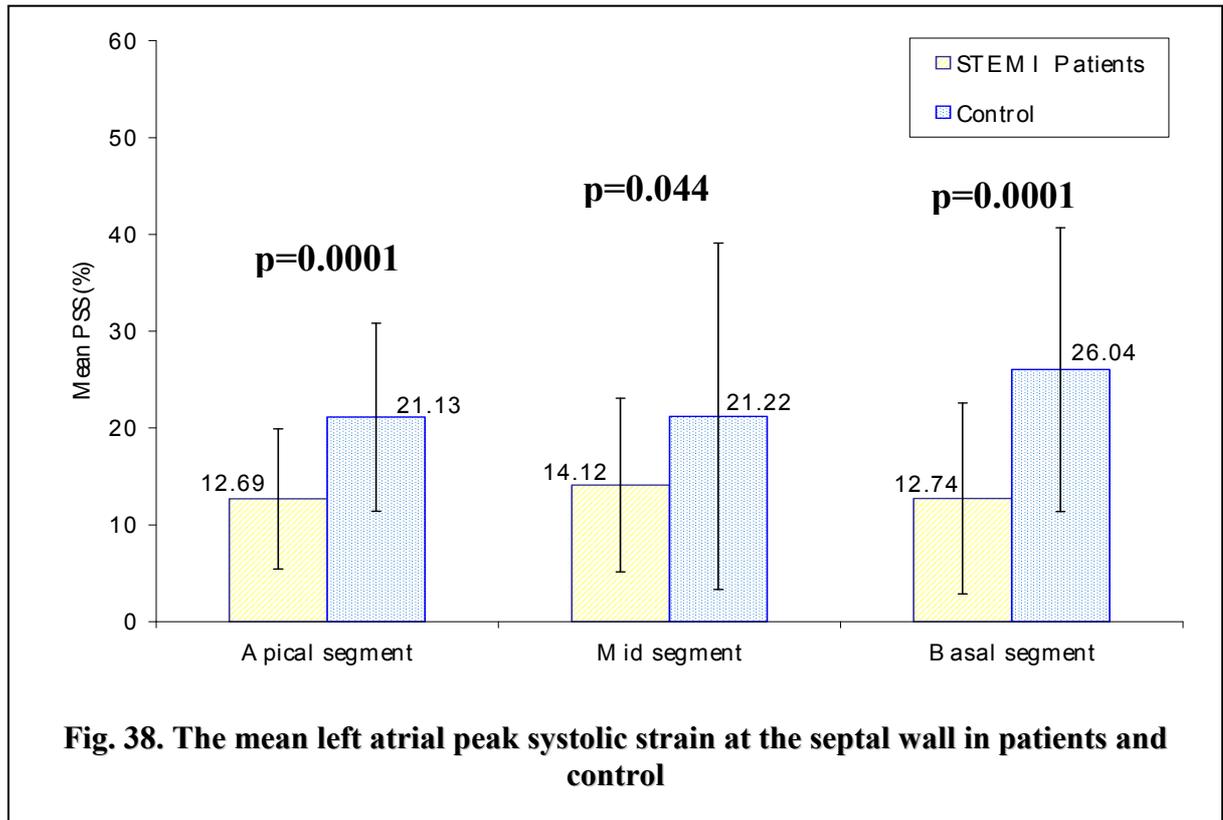
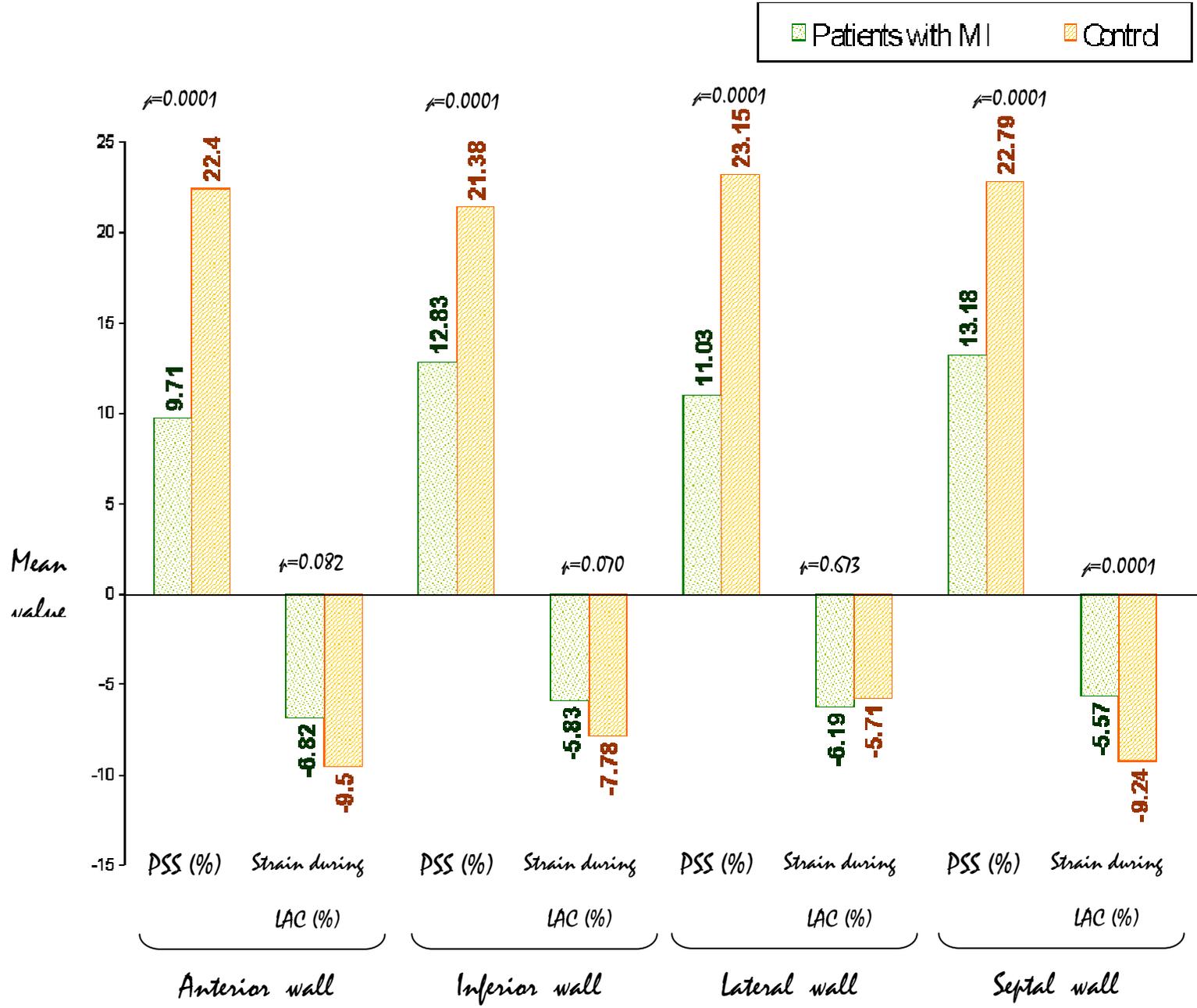


Fig. 40. The mean Tissue Doppler derived left atrial strain for all walls of left atrium in STEMI patients and control



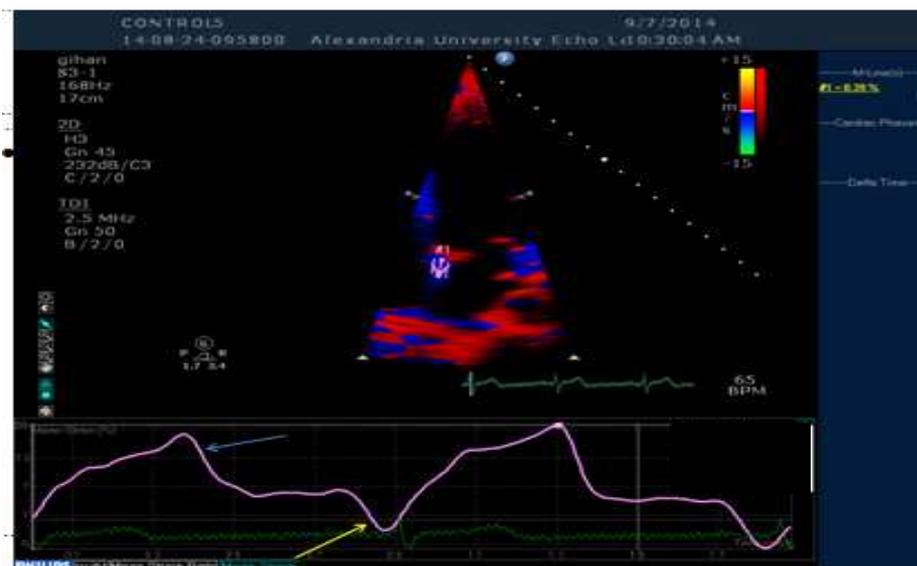


Fig. 41. Strain of the apical segment at the septal wall of control No. (5) shows PSS (blue arrow) and strain during left atrial contraction (yellow arrow)

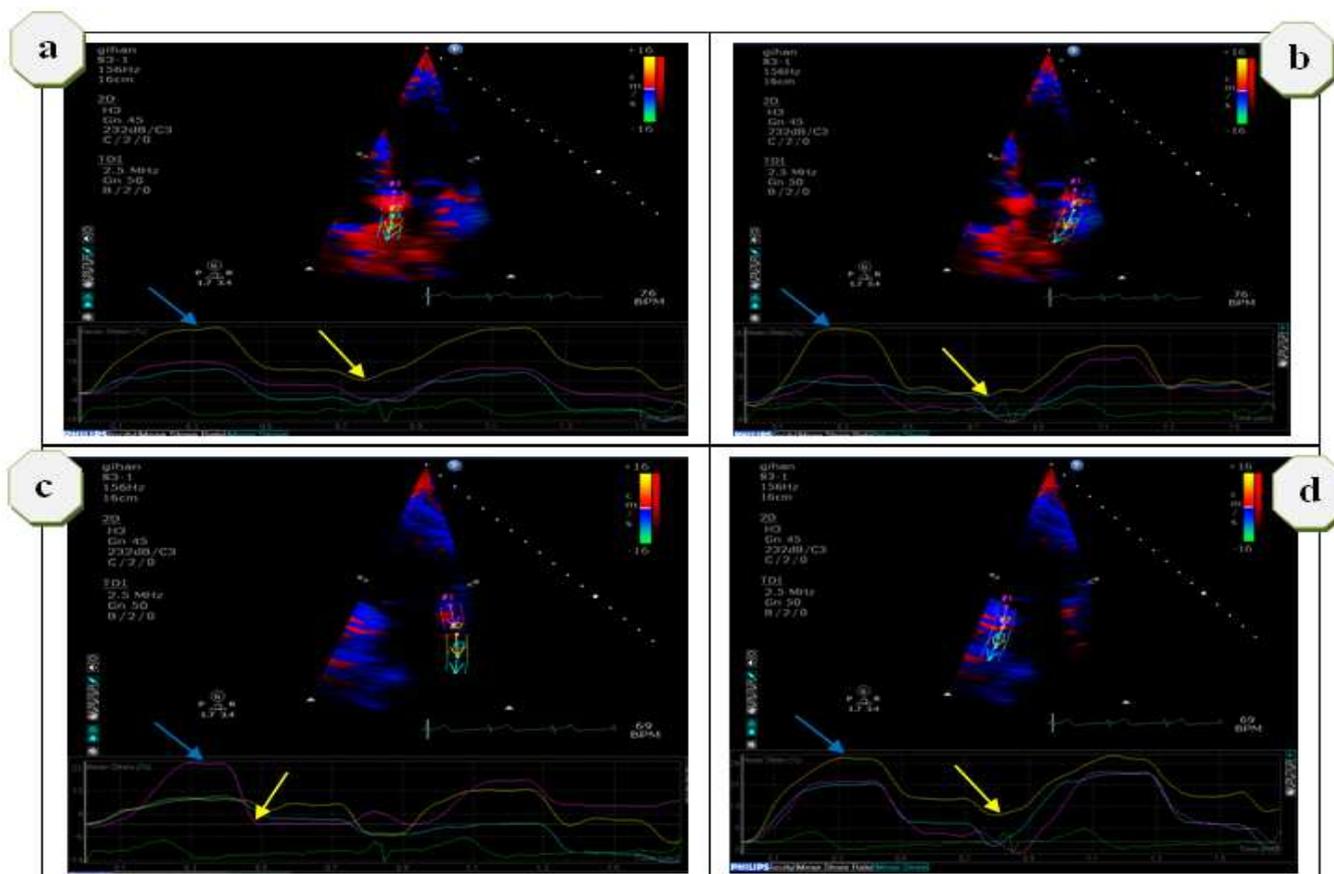
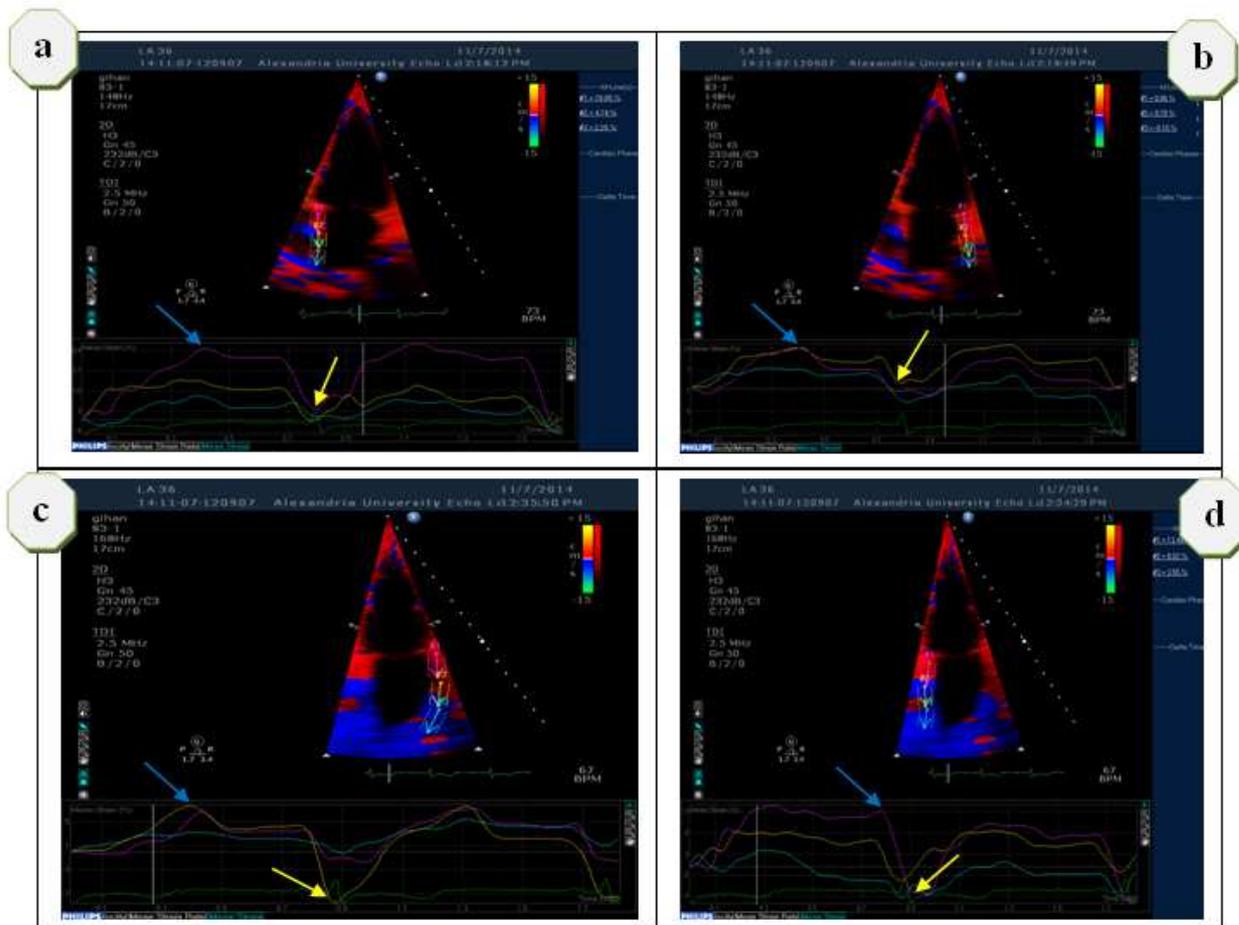


Fig. 42. Left atrial strain curves of patient No. (27) showing septal wall strain (a), lateral wall strain (b), anterior wall strain (c) and inferior wall strain (d). (PSS; blue arrow) (Strain during LAC; yellow arrow)



**Fig. 43. Left atrial strain curves of patient No. (36) showing septal wall strain(a), lateral wall strain(b), anterior wall strain(c) and inferior wall strain(d). (PSS; blue arrow) (Strain during LAC; yellow arrow)**

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**Tissue Doppler derived left atrial strain rate:****Left atrial strain rate of the anterior wall: (Table 21 and Figures 44-46, 56-58)**

The left atrial peak systolic strain rate in the apical, mid, and basal segments of patients were lower than in the control ( $1.25 \pm 0.89 \text{ S}^{-1}$  vs.  $2.28 \pm 1.05 \text{ S}^{-1}$ ;  $1.05 \pm 0.72 \text{ S}^{-1}$  vs.  $2.02 \pm 1.05 \text{ S}^{-1}$ ;  $0.67 \pm 0.51 \text{ S}^{-1}$  vs.  $0.86 \pm 0.41 \text{ S}^{-1}$  respectively). These differences were found statistically significant for apical and mid segments ( $p=0.0001$ ,  $p=0.0001$  respectively) and insignificant for basal segment ( $p=0.148$ ).

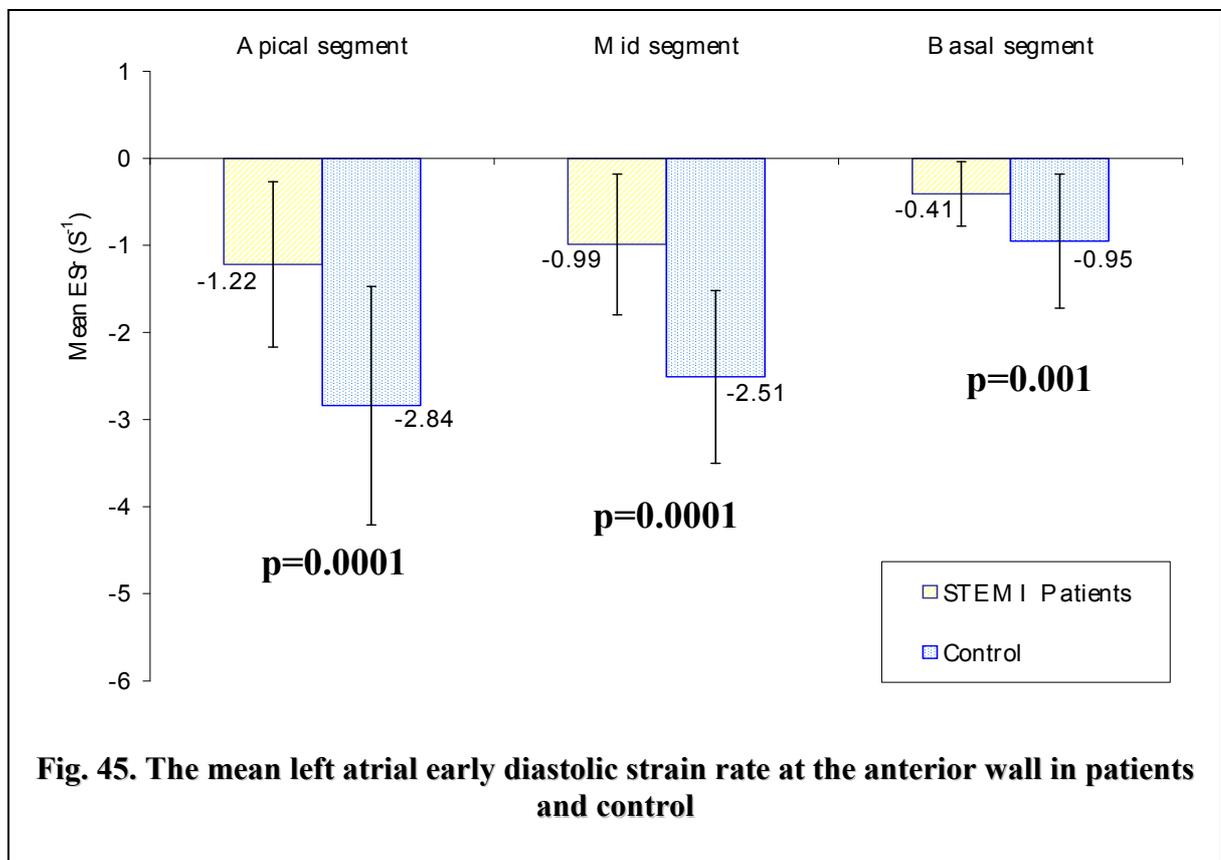
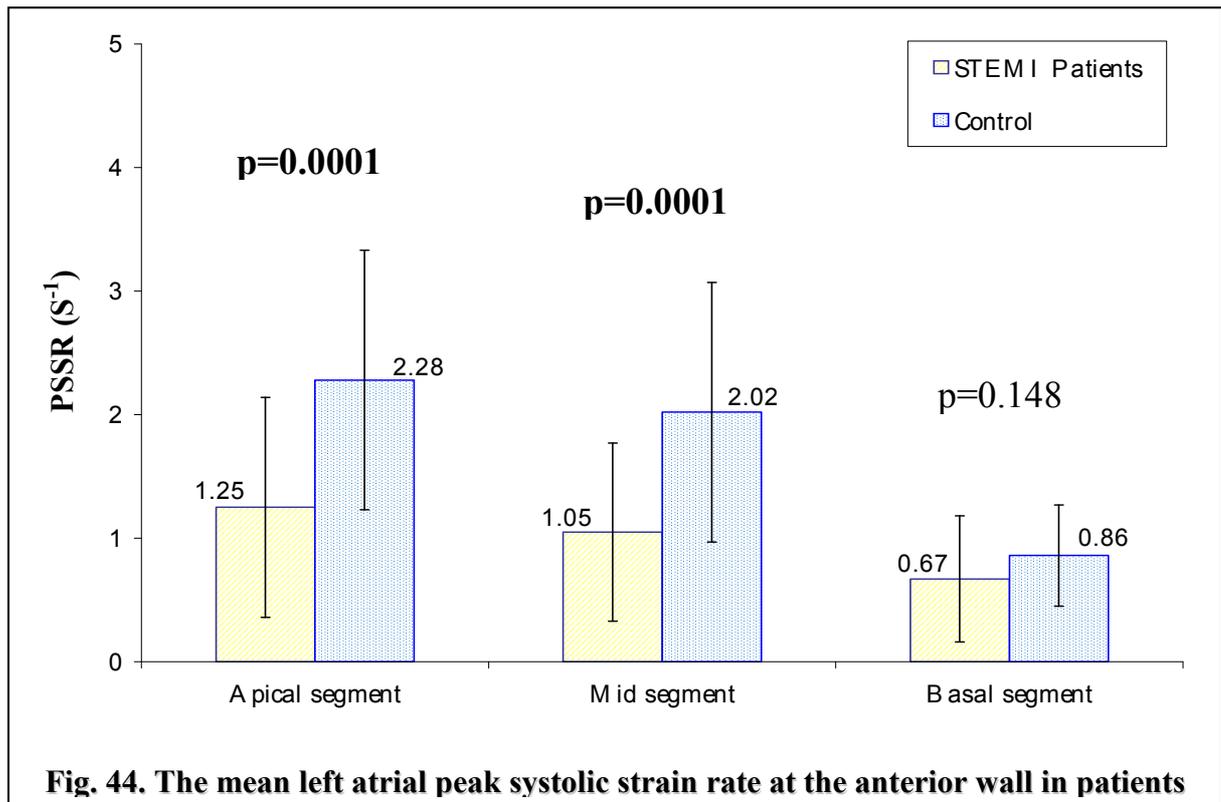
Even the mean left atrial peak systolic strain rate of the anterior wall was significantly lower in patients ( $0.99 \pm 0.50 \text{ S}^{-1}$ ) than in the control ( $1.72 \pm 0.50 \text{ S}^{-1}$ ) and this was found statistically significant ( $p = 0.0001$ ).

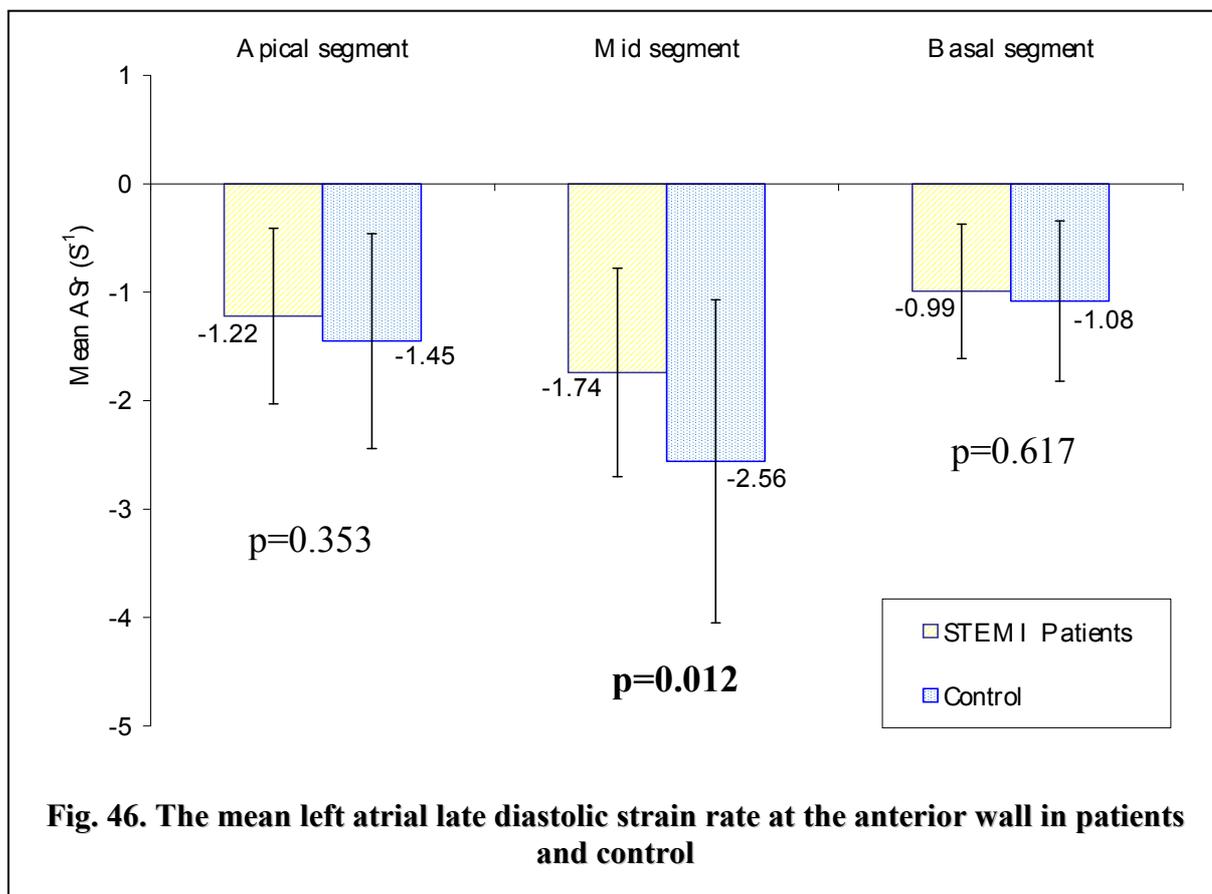
The early diastolic strain rate (ESr) of the anterior wall at the apical, mid and basal segments in patients group ( $-1.22 \pm 0.95 \text{ S}^{-1}$ ;  $-0.99 \pm 0.81 \text{ S}^{-1}$ ;  $-0.41 \pm 0.37 \text{ S}^{-1}$ ) were lower than in the control group ( $-2.84 \pm 1.37 \text{ S}^{-1}$ ;  $-2.51 \pm 0.99 \text{ S}^{-1}$ ;  $-0.95 \pm 0.77 \text{ S}^{-1}$ ) respectively. These differences were found statistically significant ( $p= 0.0001$ ,  $p= 0.0001$ ,  $p= 0.001$  respectively). Even the mean ESr of the anterior wall was significantly lower among patients than in the control ( $-0.88 \pm 0.55 \text{ S}^{-1}$  vs.  $-2.10 \pm 0.74 \text{ S}^{-1}$ ) with  $p=0.0001$ .

The late diastolic strain rate (ASr) of the anterior wall at the apical, mid and basal segments in patients group ( $-1.22 \pm 0.81 \text{ S}^{-1}$ ;  $-1.74 \pm 0.96 \text{ S}^{-1}$ ;  $-0.99 \pm 0.62 \text{ S}^{-1}$ ) were lower than in the control group ( $-1.45 \pm 0.99 \text{ S}^{-1}$ ;  $-2.56 \pm 1.49 \text{ S}^{-1}$ ;  $-1.08 \pm 0.74 \text{ S}^{-1}$ ) respectively. These differences were found statistically insignificant for apical and basal segments ( $p=0.353$ ,  $p=0.617$  respectively), but significant for the mid segment ( $p=0.012$ ). Even the mean ASr of the anterior wall was significantly lower among patients than in the control ( $-1.32 \pm 0.45 \text{ S}^{-1}$  vs.  $-1.69 \pm 0.64 \text{ S}^{-1}$ ) with  $p=0.0001$ .

**Table 21. Comparison between patients with myocardial infarction and the control according to atrial strain rate at the anterior wall**

Anterior wall		Patients (n= 40)	Control (n= 20)	p-value
<b>- Apical segment:</b>				
PSSR (S <sup>-1</sup> ):	Min. – Max.	0.30 – 4.17	1.07 – 5.08	<b>0.0001*</b>
	Mean ± SD	1.25 ± 0.89	2.28 ± 1.05	
	Median	0.98	2.07	
ESr (s <sup>-1</sup> ):	Min. – Max.	-0.17 – -4.0	-0.71 – -5.57	<b>0.0001*</b>
	Mean ± SD	-1.22 ± 0.95	-2.84 ± 1.37	
	Median	-1.03	-2.52	
ASr (s <sup>-1</sup> ):	Min. – Max.	-0.20 – -4.00	-0.06 – -3.92	0.353
	Mean ± SD	-1.22 ± 0.81	-1.45 ± 0.99	
	Median	-1.06	-1.21	
<b>- Mid segment:</b>				
PSSR (S <sup>-1</sup> ):	Min. – Max.	0.15 – 2.99	0.97 – 5.40	<b>0.0001*</b>
	Mean ± SD	1.05 ± 0.72	2.02 ± 1.05	
	Median	0.83	1.73	
ESr (s <sup>-1</sup> ):	Min. – Max.	-0.09 – -3.64	-1.47 – -5.44	<b>0.0001*</b>
	Mean ± SD	-0.99 ± 0.81	-2.51 ± 0.99	
	Median	-0.90	-2.20	
ASr (s <sup>-1</sup> ):	Min. – Max.	-0.07 – -4.89	-0.60 – -6.43	<b>0.012*</b>
	Mean ± SD	-1.74 ± 0.96	-2.56 ± 1.49	
	Median	-1.48	-2.16	
<b>-Basal segment</b>				
PSSR (S <sup>-1</sup> ):	Min. – Max.	0.05 – 2.21	0.27 – 1.68	0.148
	Mean ± SD	0.67 ± 0.51	0.86 ± 0.41	
	Median	0.51	0.85	
ESr (s <sup>-1</sup> ):	Min. – Max.	-0.01 – -1.45	-0.12 – -3.75	<b>0.001*</b>
	Mean ± SD	-0.41 ± 0.37	-0.95 ± 0.77	
	Median	-0.29	-0.80	
ASr (s <sup>-1</sup> ):	Min. – Max.	-0.01 – -2.88	-0.20 – -2.44	0.617
	Mean ± SD	-0.99 ± 0.62	-1.08 ± 0.74	
	Median	-0.86	-0.75	
<b>Mean anterior wall PSSR (S<sup>-1</sup>):</b>				
	Min. - Max.	0.19 – 2.55	1.02 – 3.10	<b>0.0001*</b>
	Mean ± SD	0.99 ± 0.50	1.72 ± 0.50	
	Median	0.98	1.61	
<b>Mean anterior wall ESr (S<sup>-1</sup>):</b>				
	Min. - Max.	-0.17 – -2.65	-1.05 – -4.21	<b>0.0001*</b>
	Mean ± SD	-0.88 ± 0.55	-2.10 ± 0.74	
	Median	-0.71	-1.93	
<b>Mean anterior wall ASr (S<sup>-1</sup>):</b>				
	Min. - Max.	-0.60 – -2.41	-0.54 – -3.32	<b>0.0001*</b>
	Mean ± SD	-1.32 ± 0.45	-1.69 ± 0.64	
	Median	-1.23	-1.55	
PSSR: peak systolic strain rate      ESr, early diastolic atrial strain rate      ASr: late diastolic atrial strain rate				
Student t- test for the difference between two means      *Statistically significant				





**Fig. 46. The mean left atrial late diastolic strain rate at the anterior wall in patients and control**

**Left atrial strain rate of the inferior wall: (Table 22 and Figures 47 - 49, 56-58)**

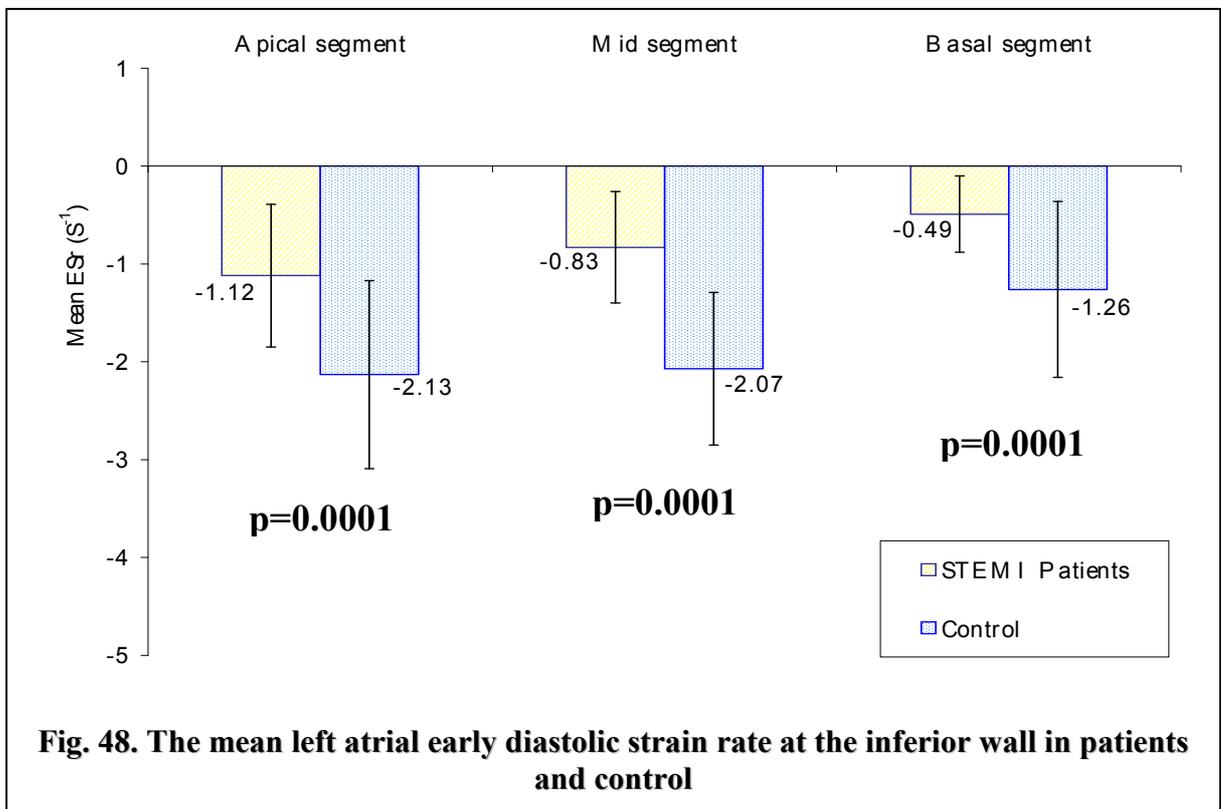
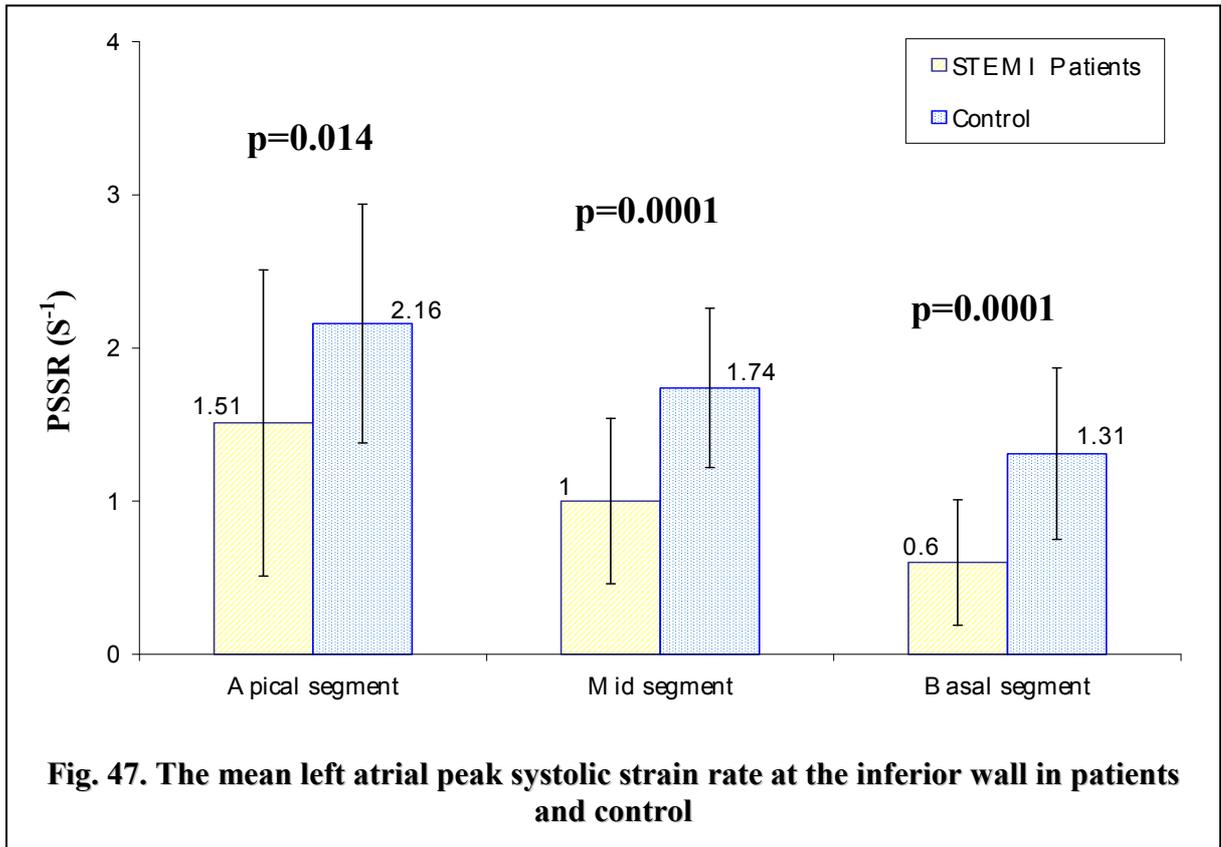
The left atrial peak systolic strain rate in the apical, mid, and basal segments of patients were lower than in the control ( $1.51 \pm 1.00 \text{ S}^{-1}$  vs.  $2.16 \pm 0.78 \text{ S}^{-1}$ ;  $1.00 \pm 0.54 \text{ S}^{-1}$  vs.  $1.74 \pm 0.52 \text{ S}^{-1}$ ;  $0.60 \pm 0.41 \text{ S}^{-1}$  vs.  $1.31 \pm 0.56 \text{ S}^{-1}$  respectively). These differences were found statistically significant ( $p=0.014$ ,  $p=0.0001$ ,  $p=0.0001$  respectively). Similarly, the mean left atrial peak systolic strain rate of the inferior wall was significantly lower in patients ( $1.03 \pm 0.51 \text{ S}^{-1}$ ) than in the control ( $1.74 \pm 0.33 \text{ S}^{-1}$ ) and this was found statistically significant ( $p = 0.0001$ ).

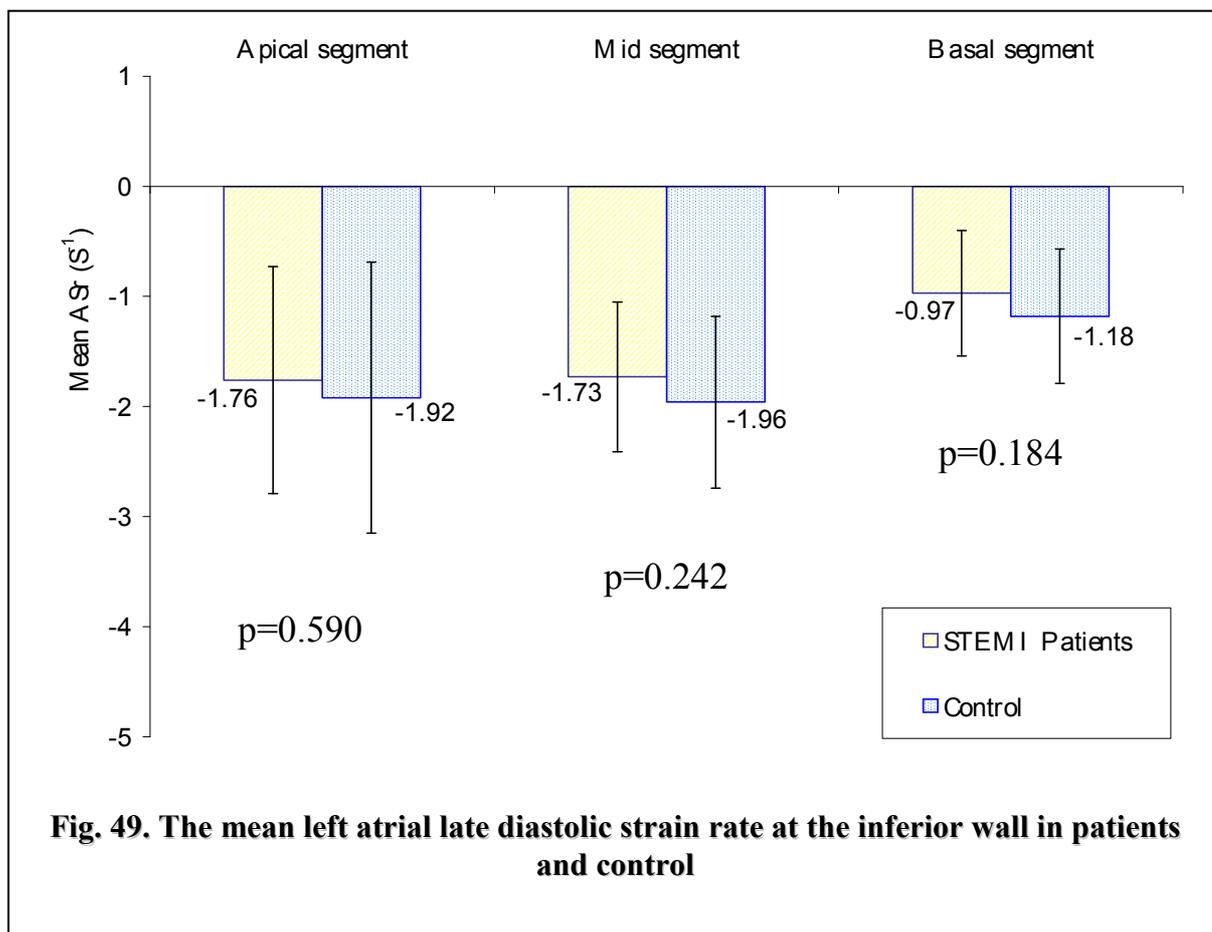
The early diastolic strain rate (ESr) of the inferior wall at the apical, mid and basal segments in patients group ( $-1.12 \pm 0.73 \text{ S}^{-1}$ ;  $-0.83 \pm 0.57 \text{ S}^{-1}$ ;  $-0.49 \pm 0.39 \text{ S}^{-1}$ ) were lower than in the control group ( $-2.13 \pm 0.96 \text{ S}^{-1}$ ;  $-2.07 \pm 0.78 \text{ S}^{-1}$ ;  $-1.26 \pm 0.90 \text{ S}^{-1}$ ) respectively. These differences were found statistically significant ( $p= 0.0001$ ,  $p= 0.0001$ ,  $p= 0.0001$  respectively). The mean ESr of the inferior wall was significantly lower among patients than in the control ( $-0.83 \pm 0.48 \text{ S}^{-1}$  vs.  $-1.82 \pm 0.62 \text{ S}^{-1}$ ) with  $p=0.0001$ .

The late diastolic strain rate (ASr) of the inferior wall at the apical, mid and basal segments in patients group ( $-1.76 \pm 1.03 \text{ S}^{-1}$ ;  $-1.73 \pm 0.68 \text{ S}^{-1}$ ;  $-0.97 \pm 0.57 \text{ S}^{-1}$ ) were lower than in the control group ( $-1.92 \pm 1.23 \text{ S}^{-1}$ ;  $-1.96 \pm 0.78 \text{ S}^{-1}$ ;  $-1.18 \pm 0.61 \text{ S}^{-1}$ ) respectively. These differences were found statistically insignificant ( $p=0.590$ ,  $p=0.242$ ,  $p=0.184$  respectively). The mean ASr of the inferior wall was insignificantly lower among patients than in the control ( $-1.49 \pm 0.40 \text{ S}^{-1}$  vs.  $-1.69 \pm 0.51 \text{ S}^{-1}$ ) with  $p=0.097$ .

**Table 22. Comparison between patients with myocardial infarction and the control according to atrial strain rate at the inferior wall**

Inferior wall		Patients (n= 40)	Control (n= 20)	p-value
<b>- Apical segment:</b>				
PSSR (S <sup>-1</sup> ):	Min. – Max.	0.31 - 3.93	0.89 - 3.64	<b>0.014*</b>
	Mean ± SD	1.51 ± 1.00	2.16 ± 0.78	
	Median	1.21	2.08	
ESr (s <sup>-1</sup> ):	Min. – Max.	- 0.05 - -3.36	-0.97 - -4.76	<b>0.0001*</b>
	Mean ± SD	-1.12 ± 0.73	-2.13 ± 0.96	
	Median	-0.89	-1.81	
ASr (s <sup>-1</sup> ):	Min. – Max.	-0.63 - -5.78	-0.22 - -5.49	0.590
	Mean ± SD	-1.76 ± 1.03	-1.92 ± 1.23	
	Median	-1.47	-2.0	
<b>- Mid segment:</b>				
PSSR (S <sup>-1</sup> ):	Min. – Max.	0.02 - 2.36	0.93 - 2.48	<b>0.0001*</b>
	Mean ± SD	1.00 ± 0.54	1.74 ± 0.52	
	Median	0.96	1.70	
ESr (s <sup>-1</sup> ):	Min. – Max.	-0.01 - -2.61	-0.65 - -4.09	<b>0.0001*</b>
	Mean ± SD	-0.83 ± 0.57	-2.07 ± 0.78	
	Median	-0.72	-2.08	
ASr (s <sup>-1</sup> ):	Min. – Max.	-0.08 - -3.27	-1.05 - -3.53	0.242
	Mean ± SD	-1.73 ± 0.68	-1.96 ± 0.78	
	Median	-1.76	-1.81	
<b>-Basal segment</b>				
PSSR (S <sup>-1</sup> ):	Min. – Max.	0.05 - 1.55	0.32 - 2.36	<b>0.0001*</b>
	Mean ± SD	0.60 ± 0.41	1.31 ± 0.56	
	Median	0.53	1.26	
ESr (s <sup>-1</sup> ):	Min. – Max.	-0.04 - -2.15	-0.14 - -3.26	<b>0.0001*</b>
	Mean ± SD	-0.49 ± 0.39	-1.26 ± 0.90	
	Median	-0.34	-0.95	
ASr (s <sup>-1</sup> ):	Min. – Max.	-0.10 - -2.57	-0.19 - -2.13	0.184
	Mean ± SD	-0.97 ± 0.57	-1.18 ± 0.61	
	Median	-0.85	-1.32	
<b>Mean inferior wall PSSR (S<sup>-1</sup>):</b>				
	Min. - Max.	0.20 – 2.53	1.03 – 2.27	<b>0.0001*</b>
	Mean ± SD	1.03 ± 0.51	1.74 ± 0.33	
	Median	0.91	1.75	
<b>Mean inferior wall ESr (S<sup>-1</sup>):</b>				
	Min. - Max.	-0.03 – -2.07	-0.74 – -3.11	<b>0.0001*</b>
	Mean ± SD	-0.83 ± 0.48	-1.82 ± 0.62	
	Median	-0.77	-1.70	
<b>Mean inferior wall ASr (S<sup>-1</sup>):</b>				
	Min. - Max.	-0.75 – -2.65	-0.80 – -2.54	0.097
	Mean ± SD	-1.49 ± 0.40	-1.69 ± 0.51	
	Median	-1.39	-1.65	
PSSR: peak systolic strain rate      ESr, early diastolic atrial strain rate      ASr: late diastolic atrial strain rate				
Student t- test for the difference between two means			*Statistically significant	





**Fig. 49. The mean left atrial late diastolic strain rate at the inferior wall in patients and control**

**Left atrial strain rate of the lateral wall: (Table 23 and Figures 50 - 52, 56-58)**

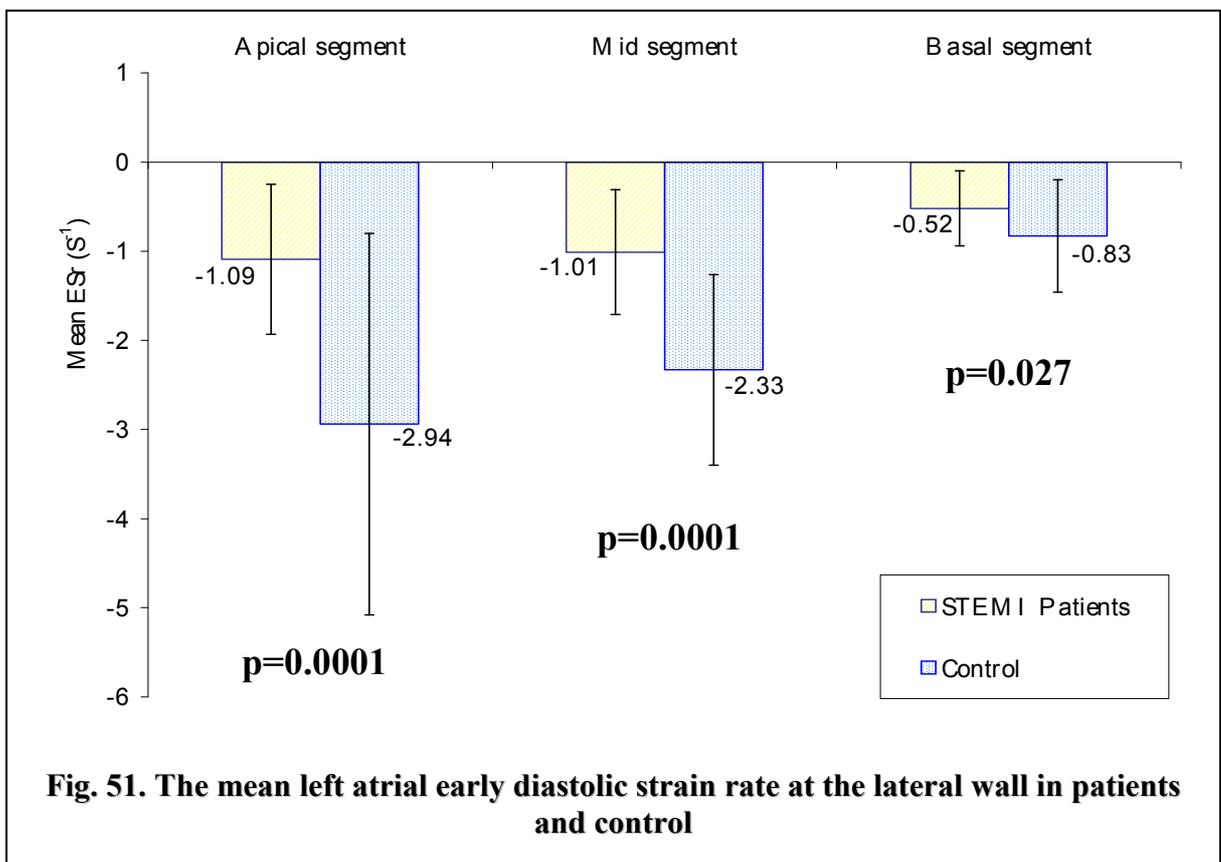
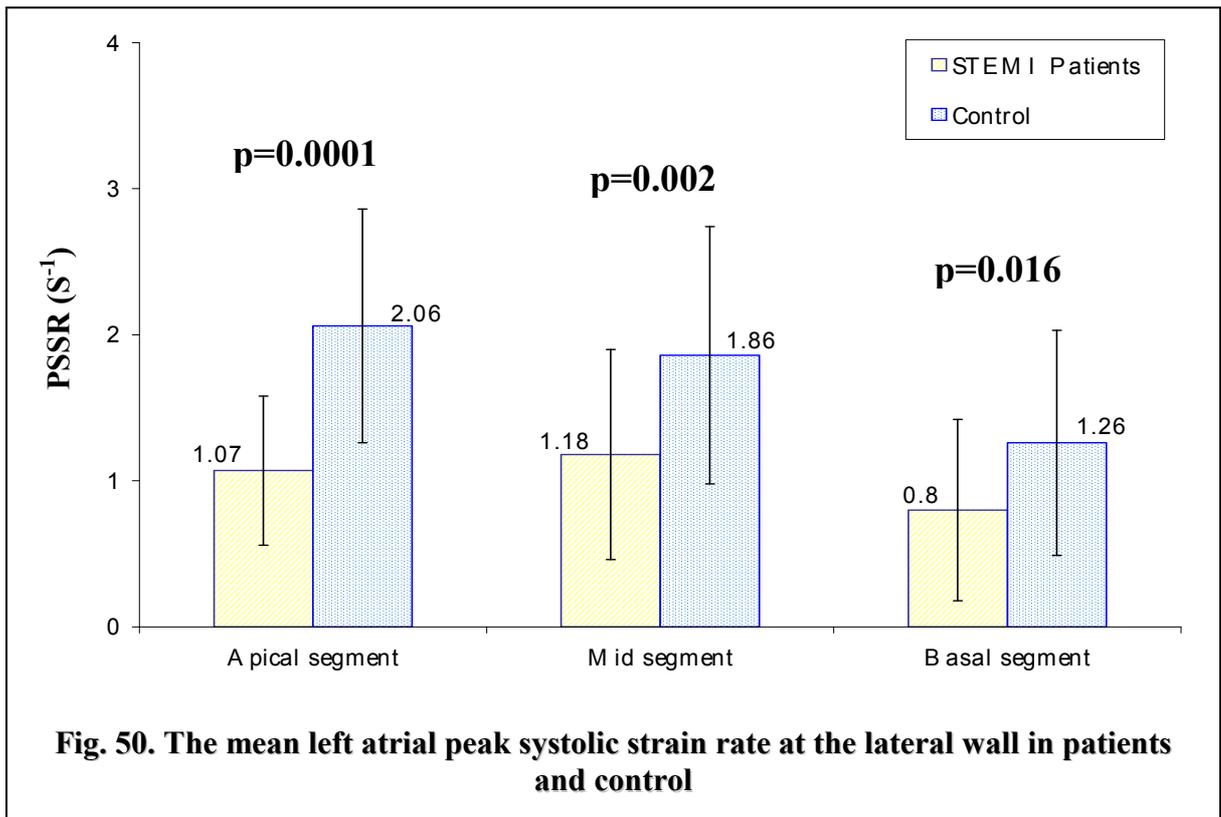
The left atrial peak systolic strain rate in the apical, mid, and basal segments of patients were lower than in the control ( $1.07\pm 0.51\text{ S}^{-1}$  vs.  $2.06\pm 0.80\text{ S}^{-1}$ ;  $1.18\pm 0.72\text{ S}^{-1}$  vs.  $1.86\pm 0.88\text{ S}^{-1}$ ;  $0.80\pm 0.62\text{ S}^{-1}$  vs.  $1.26\pm 0.77\text{ S}^{-1}$  respectively). These differences were found statistically significant ( $p=0.0001$ ,  $p=0.002$ ,  $p=0.016$  respectively). Similarly, the mean left atrial peak systolic strain rate of the lateral wall was significantly lower in patients ( $1.02\pm 0.45\text{ S}^{-1}$ ) than in the control ( $1.73\pm 0.39\text{ S}^{-1}$ ) and this was found statistically significant ( $p = 0.0001$ ).

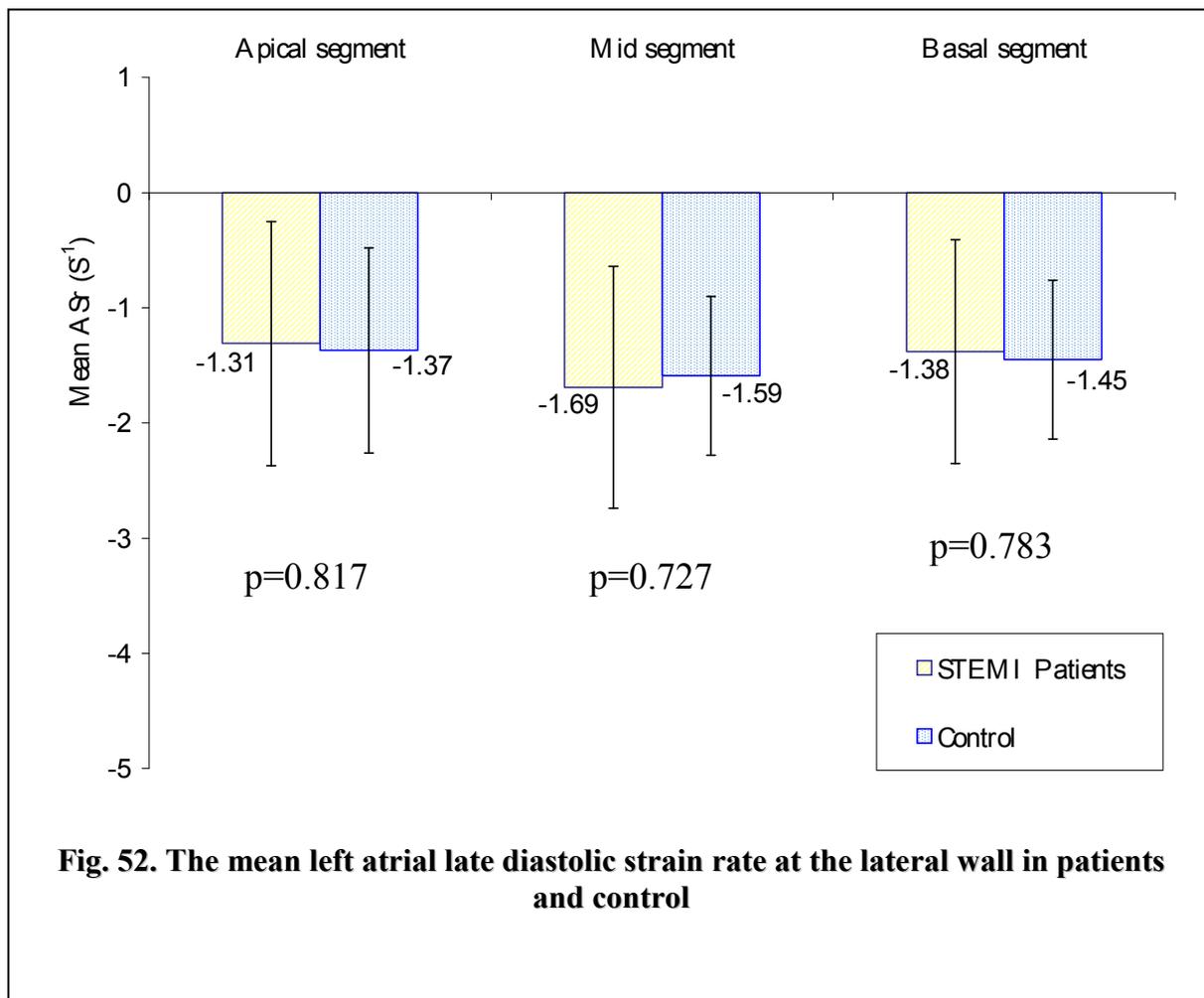
The early diastolic strain rate (ESr) of the lateral wall at the apical, mid and basal segments in patients group ( $-1.09\pm 0.84\text{ S}^{-1}$ ;  $-1.01\pm 0.70\text{ S}^{-1}$ ;  $-0.52\pm 0.42\text{ S}^{-1}$ ) were lower than in the control group ( $-2.94\pm 2.14\text{ S}^{-1}$ ;  $-2.33\pm 1.07\text{ S}^{-1}$ ;  $-0.83\pm 0.63\text{ S}^{-1}$ ) respectively. These differences were found statistically significant ( $p= 0.0001$ ,  $p= 0.0001$ ,  $p= 0.027$  respectively). The mean ESr of the lateral wall was significantly lower among patients than in the control ( $-0.87\pm 0.48\text{ S}^{-1}$  vs.  $-2.03\pm 0.92\text{ S}^{-1}$ ) with  $p=0.0001$ .

The late diastolic strain rate (ASr) of the lateral wall at the apical and basal segments in patients group ( $-1.31\pm 1.06\text{ S}^{-1}$ ;  $-1.38\pm 0.97\text{ S}^{-1}$ ) were lower than in the control group ( $-1.37\pm 0.89\text{ S}^{-1}$ ;  $-1.45\pm 0.69\text{ S}^{-1}$ ) respectively with insignificant statistical difference ( $p=0.817$ ,  $p=0.783$  respectively). For the mid segment of the lateral wall, the ASr was slightly higher among patients than in the control ( $-1.69\pm 1.05\text{ S}^{-1}$  vs.  $-1.59\pm 0.69\text{ S}^{-1}$ ) with insignificant statistical difference ( $p= 0.727$ ). The mean ASr of the lateral wall was insignificantly lower among patients than in the control ( $-1.46\pm 0.59\text{ S}^{-1}$  vs.  $-1.47\pm 0.45\text{ S}^{-1}$ ) with  $p=0.929$ .

**Table 23. Comparison between patients with myocardial infarction and the control according to atrial strain rate at the lateral wall**

Lateral wall		Patients (n= 40)	Control (n= 20)	p-value
<b>- Apical segment:</b>				
PSSR (S <sup>-1</sup> ):	Min. – Max.	0.15 - 3.15	0.75 - 3.65	<b>0.0001*</b>
	Mean ± SD	1.07 ± 0.51	2.06 ± 0.80	
	Median	0.99	2.27	
ESr (s <sup>-1</sup> ):	Min. – Max.	-0.03 - -3.13	-0.41 - -7.72	<b>0.0001*</b>
	Mean ± SD	-1.09 ± 0.84	-2.94 ± 2.14	
	Median	-1.01	-2.46	
ASr (s <sup>-1</sup> ):	Min. – Max.	-0.22 - -4.79	-0.15 - -3.56	0.817
	Mean ± SD	-1.31 ± 1.06	-1.37 ± 0.89	
	Median	-1.10	-1.29	
<b>- Mid segment:</b>				
PSSR (S <sup>-1</sup> ):	Min. – Max.	0.15 - 3.17	0.88 - 4.35	<b>0.002*</b>
	Mean ± SD	1.18 ± 0.72	1.86 ± 0.88	
	Median	0.99	1.82	
ESr (s <sup>-1</sup> ):	Min. – Max.	-0.18 - -2.77	-0.73 - -4.42	<b>0.0001*</b>
	Mean ± SD	-1.01 ± 0.70	-2.33 ± 1.07	
	Median	-0.86	-2.17	
ASr (s <sup>-1</sup> ):	Min. – Max.	-0.15 - -4.13	-0.31 - -2.89	0.727
	Mean ± SD	-1.69 ± 1.05	-1.59 ± 0.69	
	Median	-1.54	-1.74	
<b>-Basal segment</b>				
PSSR (S <sup>-1</sup> ):	Min. – Max.	0.04 - 2.60	0.05 - 2.63	<b>0.016*</b>
	Mean ± SD	0.80 ± 0.62	1.26 ± 0.77	
	Median	0.63	1.32	
ESr (s <sup>-1</sup> ):	Min. – Max.	-0.01 - -1.94	-0.03 - -2.03	<b>0.027*</b>
	Mean ± SD	-0.52 ± 0.42	-0.83 ± 0.63	
	Median	-0.44	-0.72	
ASr (s <sup>-1</sup> ):	Min. – Max.	-0.21 - -4.29	-0.33 - -3.25	0.783
	Mean ± SD	-1.38 ± 0.97	-1.45 ± 0.69	
	Median	-1.08	-1.31	
<b>Mean lateral wall PSSR (S<sup>-1</sup>):</b>				
	Min. - Max.	0.19 – 2.04	1.04 – 2.63	<b>0.0001*</b>
	Mean ± SD	1.02 ± 0.45	1.73 ± 0.39	
	Median	0.87	1.70	
<b>Mean lateral wall ESr (S<sup>-1</sup>):</b>				
	Min. - Max.	-0.14 – -2.36	-0.66 – -4.63	<b>0.0001*</b>
	Mean ± SD	-0.87 ± 0.48	-2.03 ± 0.92	
	Median	-0.78	-1.86	
<b>Mean lateral wall ASr (S<sup>-1</sup>):</b>				
	Min. - Max.	-0.54 – -2.99	-0.86 – -2.57	0.929
	Mean ± SD	-1.46 ± 0.59	-1.47 ± 0.45	
	Median	-1.41	-1.45	
PSSR: peak systolic strain rate      ESr, early diastolic atrial strain rate      ASr: late diastolic atrial strain rate				
Student t- test for the difference between two means			*Statistically significant	





**Fig. 52. The mean left atrial late diastolic strain rate at the lateral wall in patients and control**

**Left atrial strain rate of the septal wall: (Table 24 and Figures 53 - 58)**

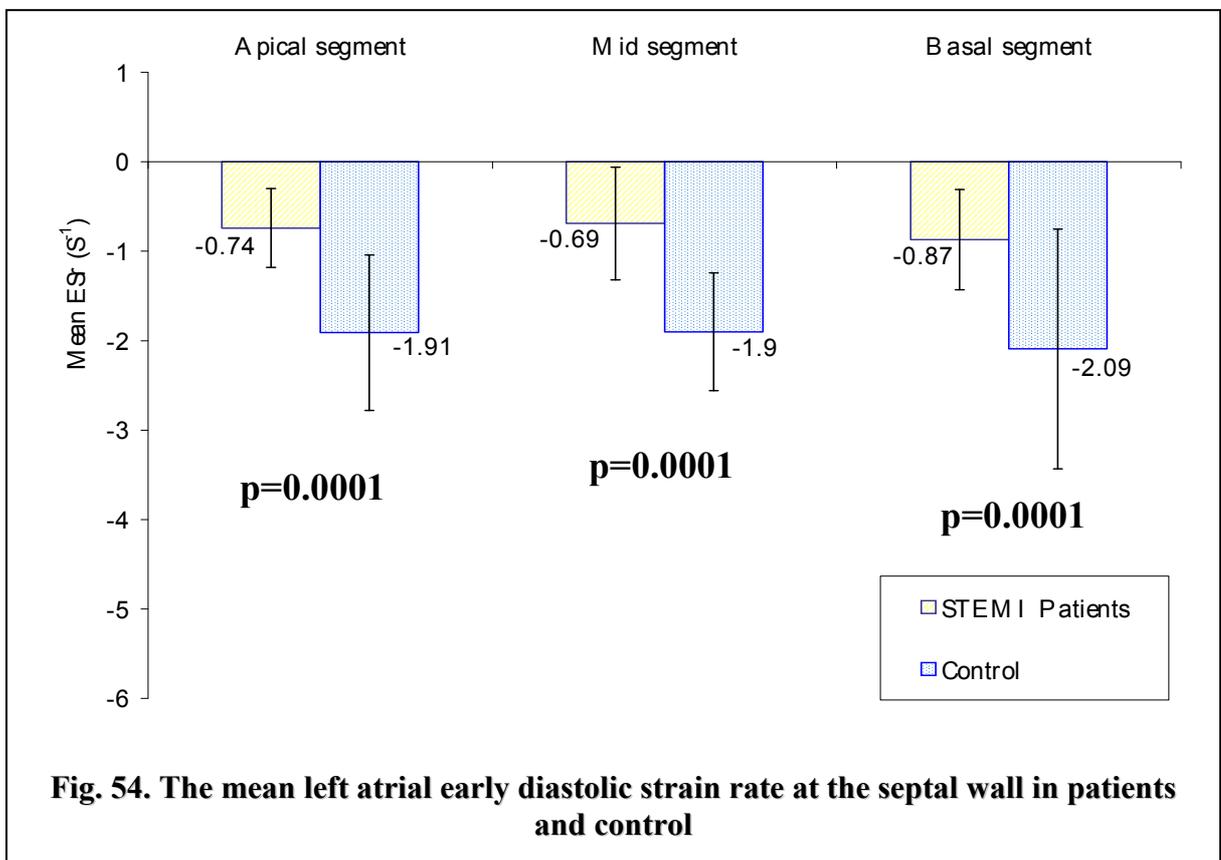
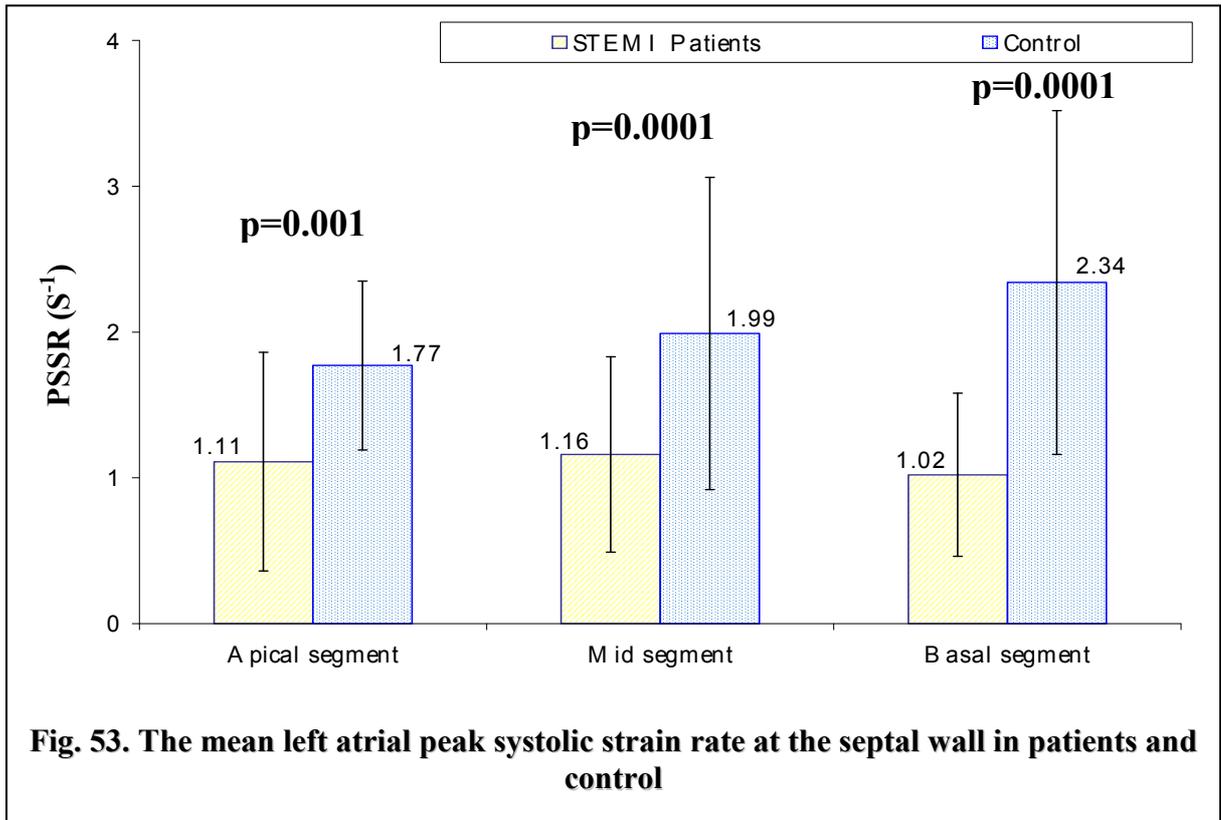
The left atrial peak systolic strain rate in the apical, mid, and basal segments of patients were lower than in the control ( $1.11\pm 0.75\text{ S}^{-1}$  vs.  $1.77\pm 0.58\text{ S}^{-1}$ ;  $1.16\pm 0.67\text{ S}^{-1}$  vs.  $1.99\pm 1.07\text{ S}^{-1}$ ;  $1.02\pm 0.56\text{ S}^{-1}$  vs.  $2.34\pm 1.18\text{ S}^{-1}$  respectively). These differences were found statistically significant ( $p=0.001$ ,  $p=0.0001$ ,  $p=0.0001$  respectively). Similarly, the mean left atrial peak systolic strain rate of the septal wall was significantly lower in patients ( $1.09\pm 0.46\text{ S}^{-1}$ ) than in the control ( $2.04\pm 0.53\text{ S}^{-1}$ ) and this was found statistically significant ( $p = 0.0001$ ).

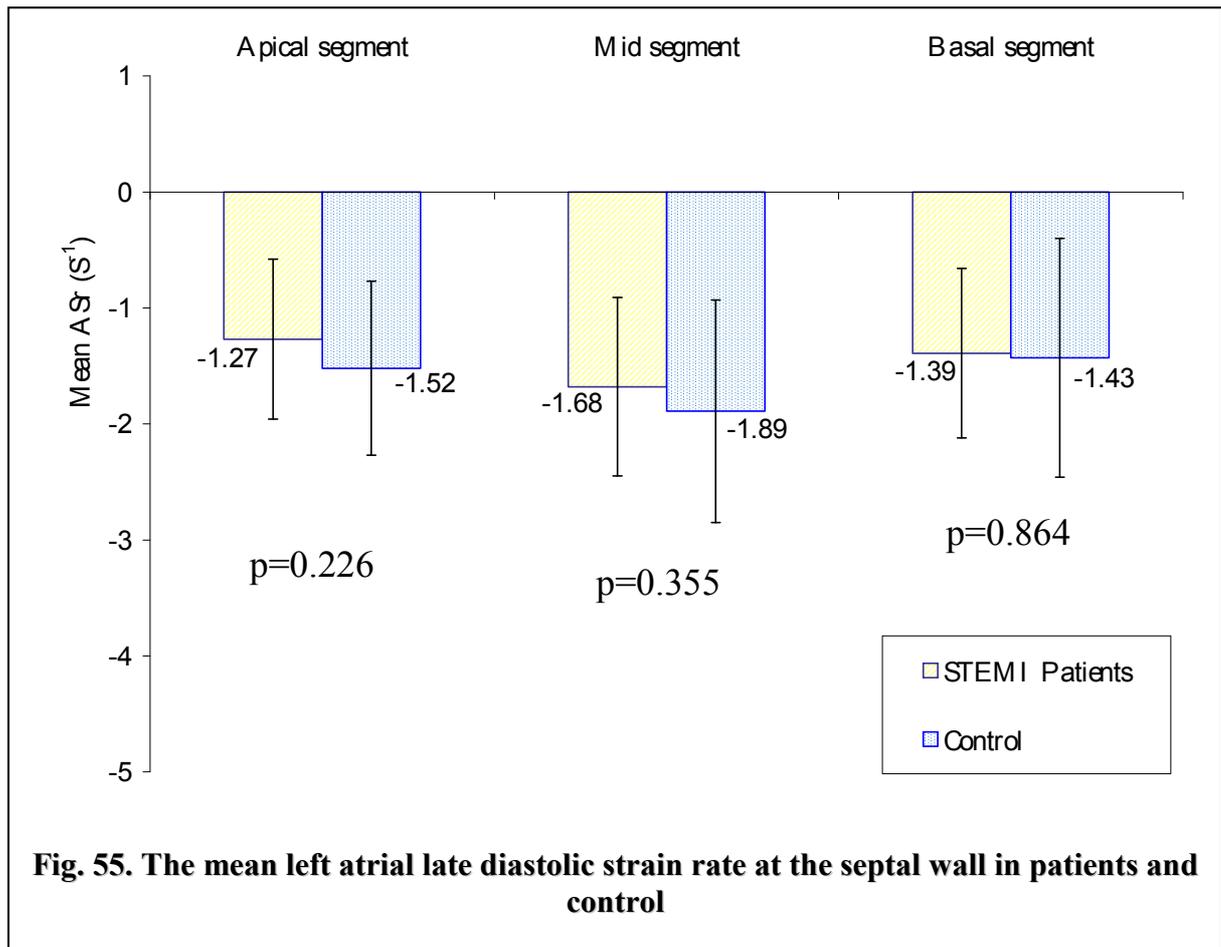
The early diastolic strain rate (ESr) of the septal wall at the apical, mid and basal segments in patients group ( $-0.74\pm 0.44\text{ S}^{-1}$ ;  $-0.69\pm 0.63\text{ S}^{-1}$ ;  $-0.87\pm 0.56\text{ S}^{-1}$ ) were lower than in the control group ( $-1.91\pm 0.87\text{ S}^{-1}$ ;  $-1.90\pm 0.66\text{ S}^{-1}$ ;  $-2.09\pm 1.34\text{ S}^{-1}$ ) respectively. These differences were found statistically significant ( $p= 0.0001$ ,  $p= 0.0001$ ,  $p= 0.0001$  respectively). The mean ESr of the septal wall was significantly lower among patients than in the control ( $-0.77\pm 0.43\text{ S}^{-1}$  vs.  $-1.97\pm 0.64\text{ S}^{-1}$ ) with  $p=0.0001$ .

The late diastolic strain rate (ASr) of the septal wall at the apical, mid and basal segments in patients group ( $-1.27\pm 0.69\text{ S}^{-1}$ ;  $-1.68\pm 0.77\text{ S}^{-1}$ ;  $-1.39\pm 0.73\text{ S}^{-1}$ ) were lower than in the control group ( $-1.52\pm 0.75\text{ S}^{-1}$ ;  $-1.89\pm 0.96\text{ S}^{-1}$ ;  $-1.43\pm 1.03\text{ S}^{-1}$ ) respectively with insignificant statistical difference ( $p= 0.226$ ,  $p= 0.355$ ,  $p= 0.864$  respectively). The mean ASr of the septal wall was insignificantly lower among patients than in the control ( $-1.45\pm 0.44\text{ S}^{-1}$  vs.  $-1.61\pm 0.57\text{ S}^{-1}$ ) with  $p= 0.225$ .

**Table 24. Comparison between patients with myocardial infarction and the control according to atrial strain rate at the septal wall**

Septal wall	Patients (n= 40)	Control (n= 20)	p-value	
<b>- Apical segment:</b>				
PSSR (S <sup>-1</sup> ):	Min. – Max. Mean ± SD Median	0.34 - 4.73 1.11 ± 0.75 0.98	0.97 - 3.36 1.77 ± 0.58 1.84	<b>0.001*</b>
ESr (s <sup>-1</sup> ):	Min. – Max. Mean ± SD Median	-0.04 - -1.77 -0.74 ± 0.44 -0.63	-0.83 - -3.67 -1.91 ± 0.87 -1.94	<b>0.0001*</b>
ASr (s <sup>-1</sup> ):	Min. – Max. Mean ± SD Median	-0.12 - -2.68 -1.27 ± 0.69 -1.13	-0.42 - -3.21 -1.52 ± 0.75 -1.37	0.226
<b>- Mid segment:</b>				
PSSR (S <sup>-1</sup> ):	Min. – Max. Mean ± SD Median	0.34 - 2.77 1.16 ± 0.67 1.02	0.60 - 5.27 1.99 ± 1.07 1.70	<b>0.0001*</b>
ESr (s <sup>-1</sup> ):	Min. – Max. Mean ± SD Median	-0.02 - -2.60 -0.69 ± 0.63 -0.47	-0.79 - -3.00 -1.90 ± 0.66 -2.02	<b>0.0001*</b>
ASr (s <sup>-1</sup> ):	Min. – Max. Mean ± SD Median	-0.31 - -3.91 -1.68 ± 0.77 -1.62	-0.50 - -4.24 -1.89 ± 0.96 -1.96	0.355
<b>-Basal segment</b>				
PSSR (S <sup>-1</sup> ):	Min. – Max. Mean ± SD Median	0.04 - 2.26 1.02 ± 0.56 0.87	0.07 - 5.02 2.34 ± 1.18 2.53	<b>0.0001*</b>
ESr (s <sup>-1</sup> ):	Min. – Max. Mean ± SD Median	-0.15 - -2.61 -0.87 ± 0.56 -0.74	-0.27 - -4.44 -2.09 ± 1.34 -1.86	<b>0.0001*</b>
ASr (s <sup>-1</sup> ):	Min. – Max. Mean ± SD Median	-0.13 - -3.65 -1.39 ± 0.73 -1.33	-0.26 - -4.44 -1.43 ± 1.03 -1.20	0.864
<b>Mean septal wall PSSR (S<sup>-1</sup>):</b>	Min. - Max. Mean ± SD Median	0.44 – 2.73 1.09 ± 0.46 1.01	1.29 – 3.39 2.04 ± 0.53 1.92	<b>0.0001*</b>
<b>Mean septal wall ESr (S<sup>-1</sup>):</b>	Min. - Max. Mean ± SD Median	-0.08 – -2.01 -0.77 ± 0.43 -0.67	-0.91 – -3.14 -1.97 ± 0.64 -1.86	<b>0.0001*</b>
<b>Mean septal wall ASr (S<sup>-1</sup>):</b>	Min. - Max. Mean ± SD Median	-0.80 – -2.52 -1.45 ± 0.44 -1.37	-0.60 – -2.94 -1.61 ± 0.57 -1.61	0.225
PSSR: peak systolic strain rate      ESr, early diastolic atrial strain rate      ASr: late diastolic atrial strain rate				
Student t- test for the difference between two means      *Statistically significant				





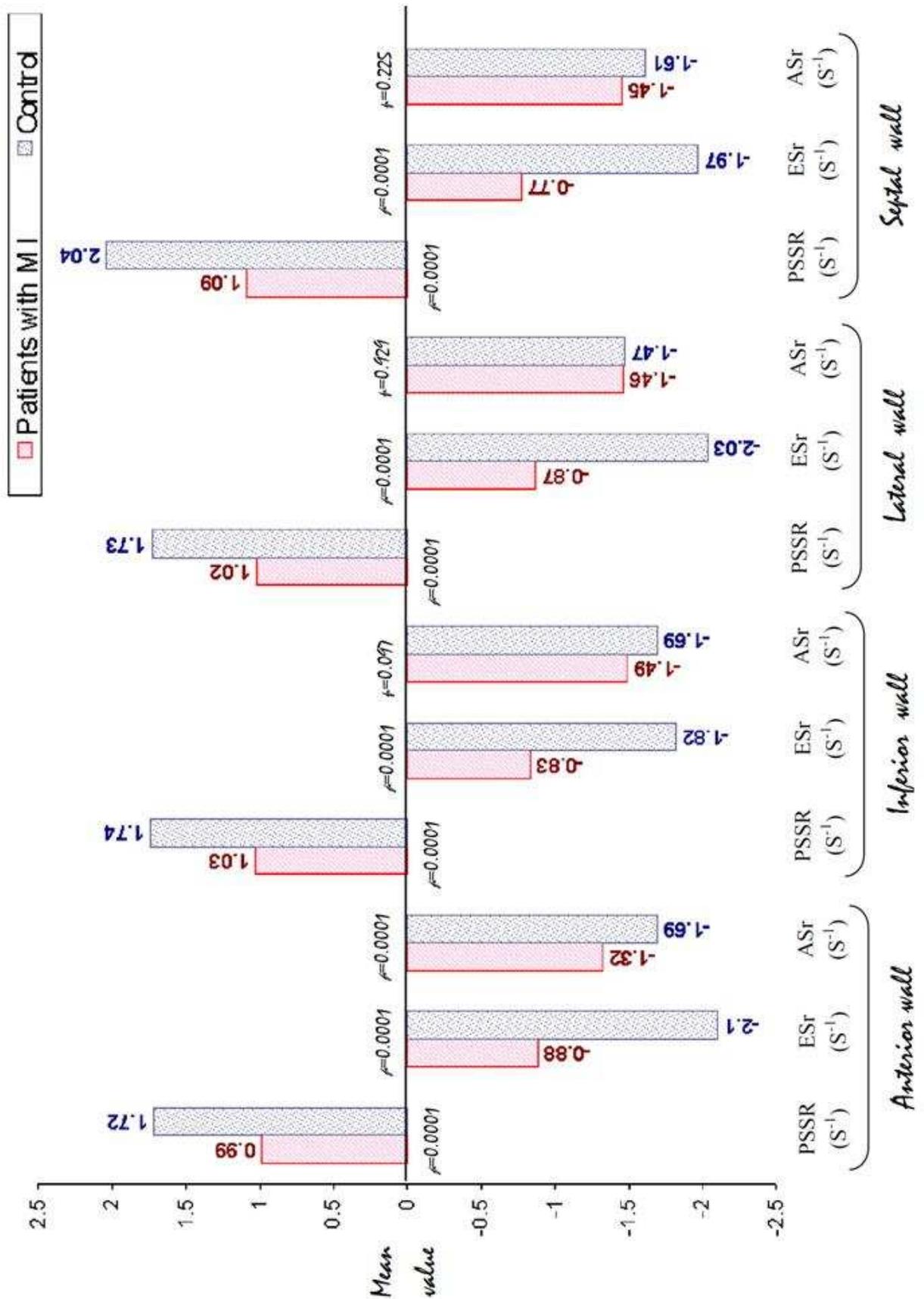
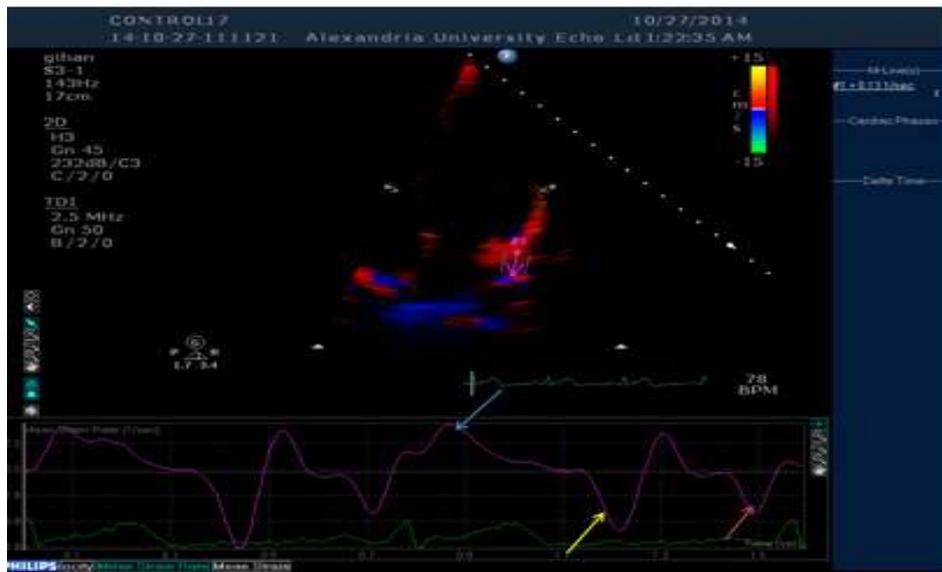
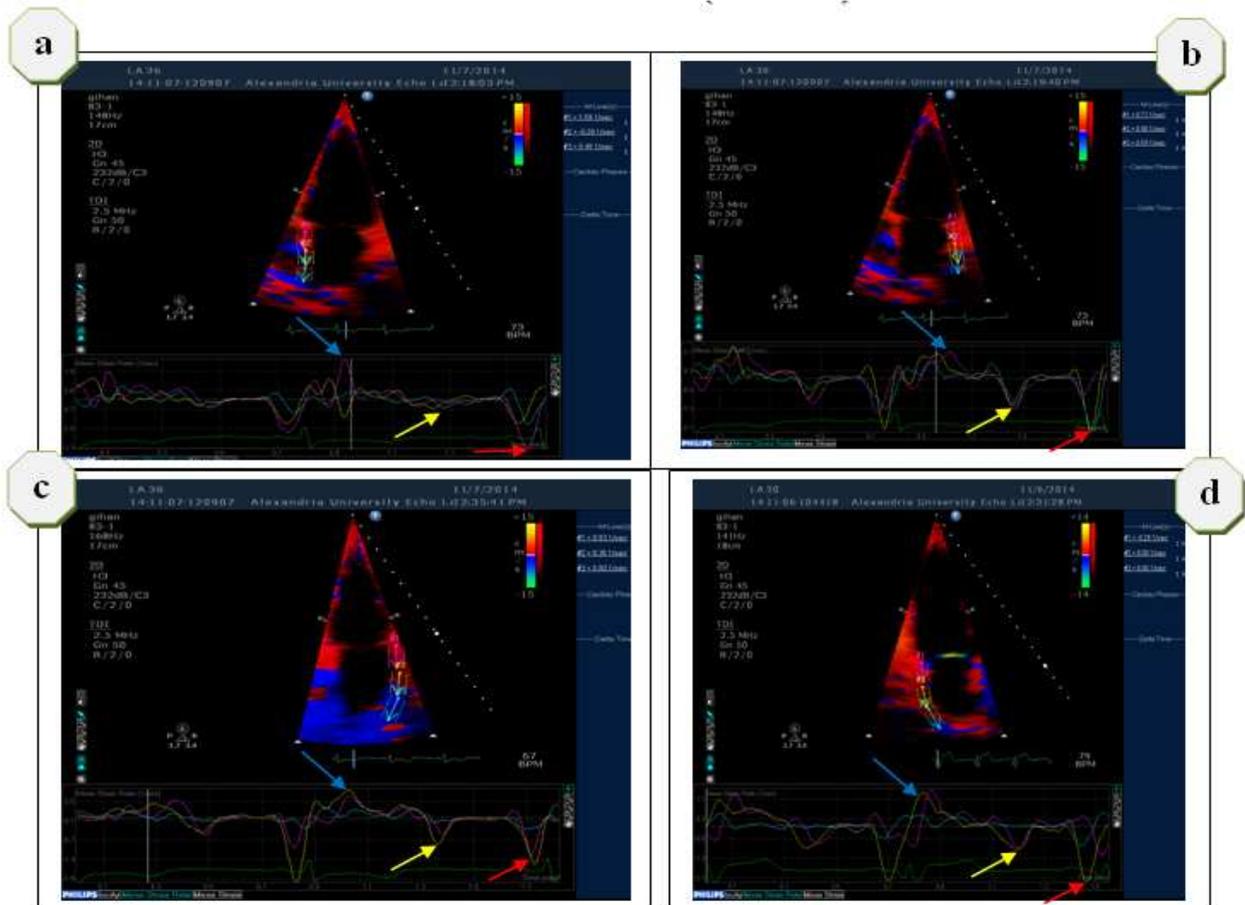


Fig. 56. The mean atrial strain rate for all walls of left atrium in patients and control



**Fig. 57. Strain rate at the apical segment of the lat wall of control No. (17) shows peak systolic strain rate (blue arrow), early diastolic strain rate (yellow arrow) and late diastolic strain rate (red arrow)**



**Fig. 58. Left atrial strain rate curves of patient No. (36) showing septal wall strain rate(a), lateral wall strain rate(b), anterior wall strain rate(c) and inferior wall strain rate(d) (PSSR: blue arrow) (ESr; yellow arrow) (ASr; red arrow)**

**The global strain and strain rate measurements (Table 25, Figures 59 and 60):**

The global PSS was significantly lower in patients with MI than in the control ( $11.69\pm 4.25\%$  vs.  $22.43\pm 3.74\%$ ) with statistically significant difference ( $p=0.0001$ ).

The global strain during left atrial contraction was significantly lower in patients with MI than in the control ( $-6.10\pm 3.49\%$  vs.  $-8.06\pm 2.40\%$ ) with statistically significant difference ( $p=0.029$ ).

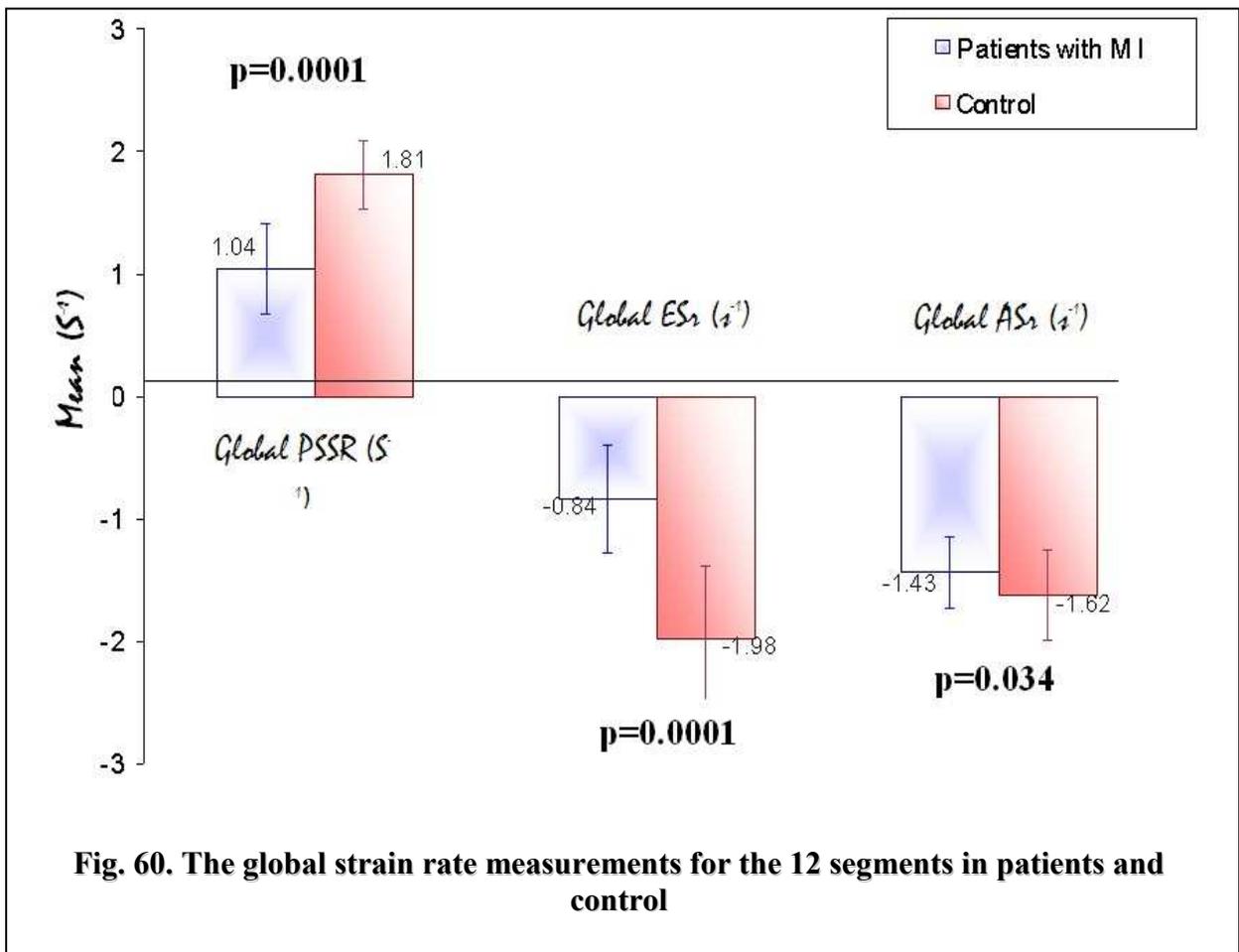
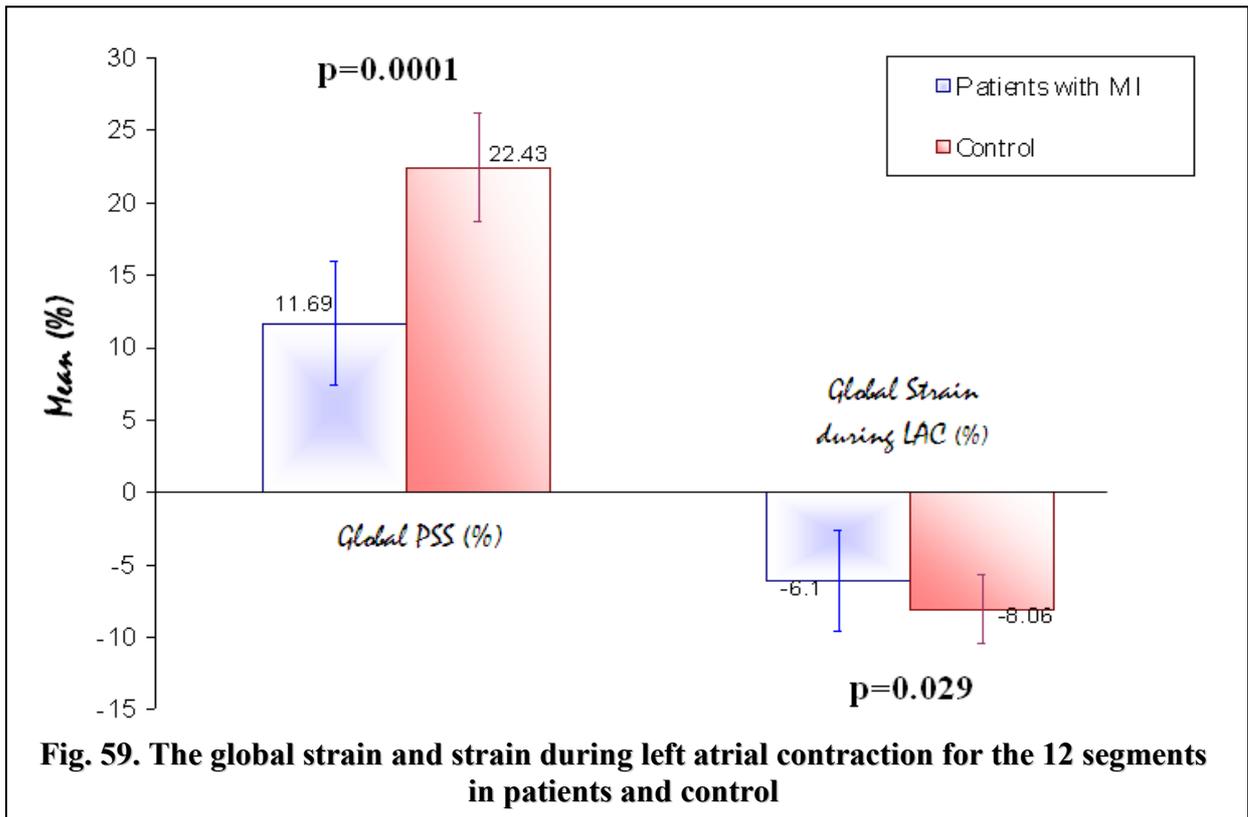
The global peak systolic strain rate was significantly lower in the studied patients than in the control ( $1.04\pm 0.37\text{ S}^{-1}$  vs.  $1.81\pm 0.28\text{ S}^{-1}$ ) with statistically significant difference ( $p=0.0001$ ).

The global early diastolic strain rate (ESr) was significantly lower among the studied patients than in the control ( $-0.84\pm 0.44\text{ S}^{-1}$  vs.  $-1.98\pm 0.60\text{ S}^{-1}$ ) with significant statistical difference ( $p=0.0001$ ).

The global late diastolic strain rate (ASr) was significantly lower among patients group than in the control group ( $-1.43\pm 0.29\text{ S}^{-1}$  vs.  $-1.62\pm 0.37\text{ S}^{-1}$ ) with significant statistical difference ( $p=0.034$ ).

**Table 25. Comparison between patients with myocardial infarction and the control according to the global strain and strain rate measurements of the 12 segments**

Measurements	Patients (n= 40)	Control (n= 20)	p-value
Global PSS (%):			
Min. - Max.	2.21 – 20.51	16.17 – 31.31	<b>0.0001*</b>
Mean ± SD	11.69 ± 4.25	22.43 ± 3.74	
Median	11.45	22.52	
Global Strain during LAC (%):			
Min. - Max.	-3.03 – -16.82	-4.07 – -13.43	<b>0.029*</b>
Mean ± SD	-6.10 ± 3.49	-8.06 ± 2.40	
Median	-5.27	-7.66	
Global PSSR (S <sup>-1</sup> ):			
Min. - Max.	0.39 – 1.84	1.32 – 2.39	<b>0.0001*</b>
Mean ± SD	1.04 ± 0.37	1.81 ± 0.28	
Median	0.94	1.74	
Global ESr (S <sup>-1</sup> ):			
Min. - Max.	-0.14 – -2.13	-0.99 – -3.48	<b>0.0001*</b>
Mean ± SD	-0.84 ± 0.44	-1.98 ± 0.60	
Median	-0.75	-1.94	
Global ASr (S <sup>-1</sup> ):			
Min. - Max.	-0.79 – -2.06	-0.98 – -2.45	<b>0.034*</b>
Mean ± SD	-1.43 ± 0.29	-1.62 ± 0.37	
Median	-1.39	-1.66	
PSS: peak systolic strain		LAC: Left atrial contraction	
ESr, early diastolic atrial strain rate		ASr: late diastolic atrial strain rate	
Student t- test for the difference between two means		*Statistically significant	



## **Correlation of the strain and strain rate of left atrium to some echocardiographic parameters (Table 26, Figure 61 - 65):**

### **The global PSS:**

The global PSS of left atrium in the studied patients with MI showed significant negative correlation to E/Ea ratio ( $r = -0.457$ ,  $p = 0.0001$ ) and the minimum left atrial volume ( $r = -0.359$ ,  $p = 0.005$ ).

There was a negative correlation between the global PSS of left atrium and the maximum left atrial volume ( $r = -0.195$ ), however, this correlation was not statistically significant ( $p = 0.135$ ).

A significant positive correlation was found between the global PSS of left atrium in the studied patients with MI and the left ventricular ejection fraction ( $r = 0.338$ ,  $p = 0.033$ ).

Also there were positive correlations between the global PSS of left atrium and the left atrial reservoir volume ( $r = 0.246$ ) and left atrial ejection fraction ( $r = 0.216$ ); however, these were not found statistically significant ( $p = 0.127$ ,  $p = 0.181$  respectively).

### **The global strain during LA contraction:**

The global strain during LA contraction showed negative correlation with LAV max. ( $r = -0.081$ ,  $p = 0.619$ ), LAV res. ( $r = -0.300$ ,  $p = 0.060$ ) and E/Ea ratio ( $r = -0.119$ ,  $p = 0.466$ ). But positive correlation to the LAV min. ( $r = 0.056$ ,  $p = 0.734$ ), LAEF ( $r = 0.271$ ,  $p = 0.091$ ) and LVEF ( $r = 0.006$ ,  $p = 0.971$ ). However, all these correlations were statistically insignificant.

### **The global peak systolic strain rate:**

The global PSSR showed positive correlations with LAV max. ( $r = 0.095$ ,  $p = 0.559$ ), LAV res. ( $r = 0.387$ ,  $p = 0.014$ ), LAEF ( $r = 0.544$ ,  $p = 0.0001$ ) and LVEF ( $r = 0.302$ ,  $p = 0.048$ ). But negative correlation to the LAV min. ( $r = -0.181$ ,  $p = 0.265$ ) and E/Ea ratio ( $r = -0.109$ ,  $p = 0.610$ ). However, these correlations were only statistically significant for LAV res., LAEF and LVEF.

### **The early diastolic strain rate (ESr):**

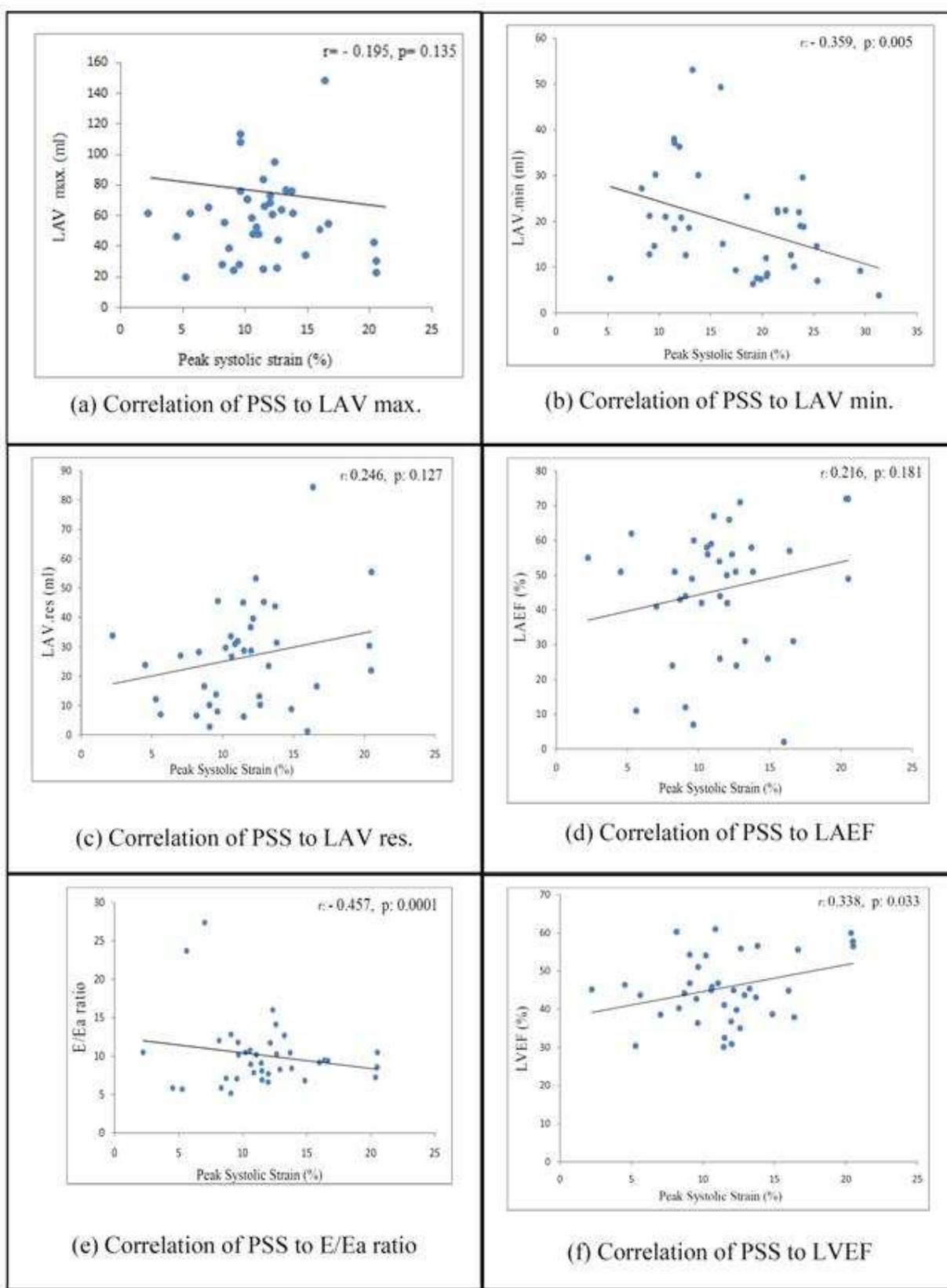
The global ESr showed negative correlations with LAV max. ( $r = -0.098$ ,  $p = 0.546$ ), LAV res. ( $r = -0.226$ ,  $p = 0.161$ ) and E/Ea ratio ( $r = -0.042$ ,  $p = 0.796$ ). But positive correlation to the LAV min. ( $r = 0.013$ ,  $p = 0.936$ ), LAEF ( $r = 0.257$ ,  $p = 0.109$ ) and LVEF ( $r = 0.399$ ,  $p = 0.011$ ). However, the global ESr showed significant correlation to the LVEF only and insignificant correlations to other parameters.

### **The late diastolic strain rate (ASr):**

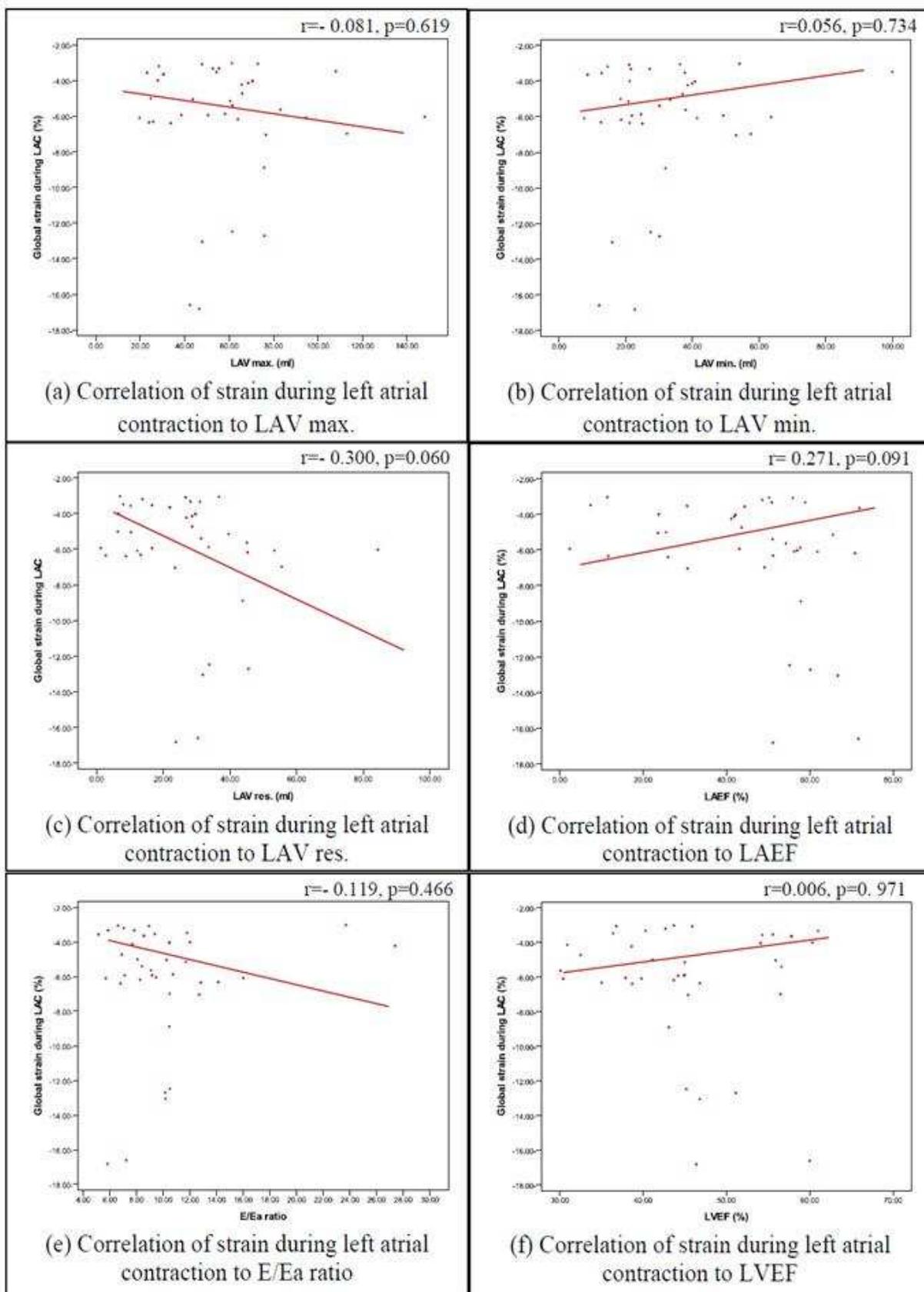
The global ASr showed positive correlations with LAV max. ( $r = 0.014$ ,  $p = 0.930$ ), LAV min. ( $r = 0.153$ ,  $p = 0.346$ ), LAEF ( $r = 0.332$ ,  $p = 0.036$ ) and E/Ea ratio ( $r = 0.102$ ,  $p = 0.529$ ). But negative correlations to LAV res. ( $r = -0.294$ ,  $p = 0.065$ ), and LVEF ( $r = -0.001$ ,  $p = 0.993$ ). However, the global ASr showed significant correlation to the LAEF only and insignificant correlations to other parameters.

**Table 26. Correlation of strain and strain rate of left atrium to some echocardiographic parameters in patients with STEMI**

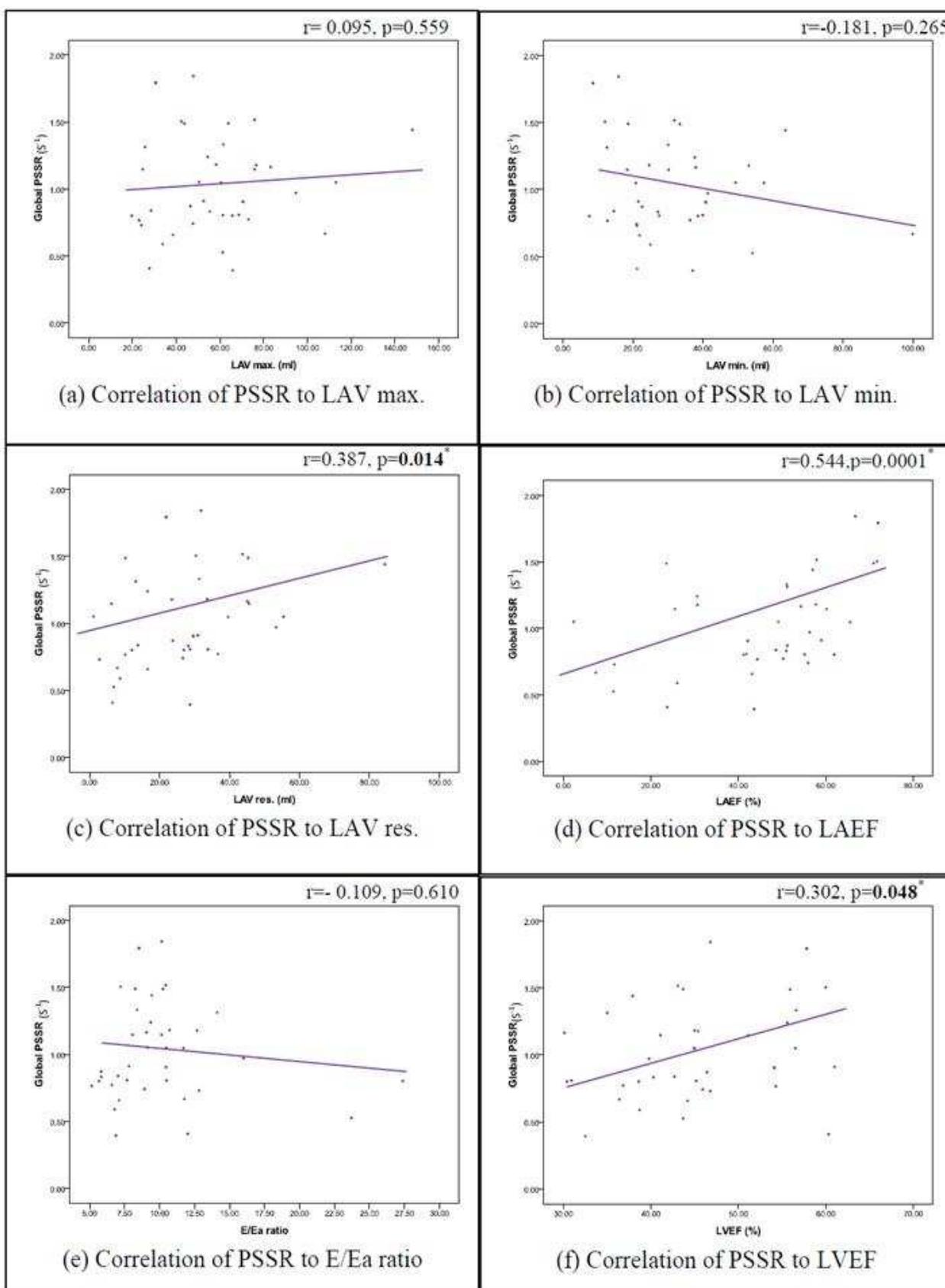
Strain and strain rate		Echocardiographic parameters in STEMI patients (n = 40)					
		LAV max(ml)	LAV min (ml)	LAV res (ml)	LAEF (%)	E/Ea ratio	LVEF (%)
PSS (%)	r	- 0.195	- 0.359	0.246	0.216	- 0.457	0.338
	p	0.135	<b>0.005*</b>	0.127	0.181	<b>0.0001*</b>	<b>0.033*</b>
Strain during LA contraction (%)	r	- 0.081	0.056	- 0.300	0.271	- 0.119	0.006
	p	0.619	0.734	0.060	0.091	0.466	0.971
PSSR (S <sup>-1</sup> )	r	0.095	- 0.181	0.387	0.544	- 0.109	0.302
	p	0.559	0.265	<b>0.014*</b>	<b>0.0001*</b>	0.610	<b>0.048*</b>
ESr (S <sup>-1</sup> )	r	- 0.098	0.013	- 0.226	0.257	- 0.042	0.399
	p	0.546	0.936	0.161	0.109	0.796	<b>0.011*</b>
ASr (S <sup>-1</sup> )	r	0.014	0.153	- 0.294	0.332	0.102	- 0.001
	p	0.930	0.346	0.065	<b>0.036*</b>	0.529	0.993
LVEF: left ventricular ejection fraction		E: pulse wave Doppler early diastolic velocity					
Ea: early diastolic tissue velocity		LAEF: left atrial ejection fraction					
LAV max: Maximum left atrial volume		LAV min: Minimum left atrial volume					
LAV res: left atrial reservoir volume		PSS: peak systolic strain					
PSSR: peak systolic strain rate		ESr: early diastolic strain rate					
ASr: late diastolic strain rate							
r: Pearson correlation coefficient		*Statistically significant					



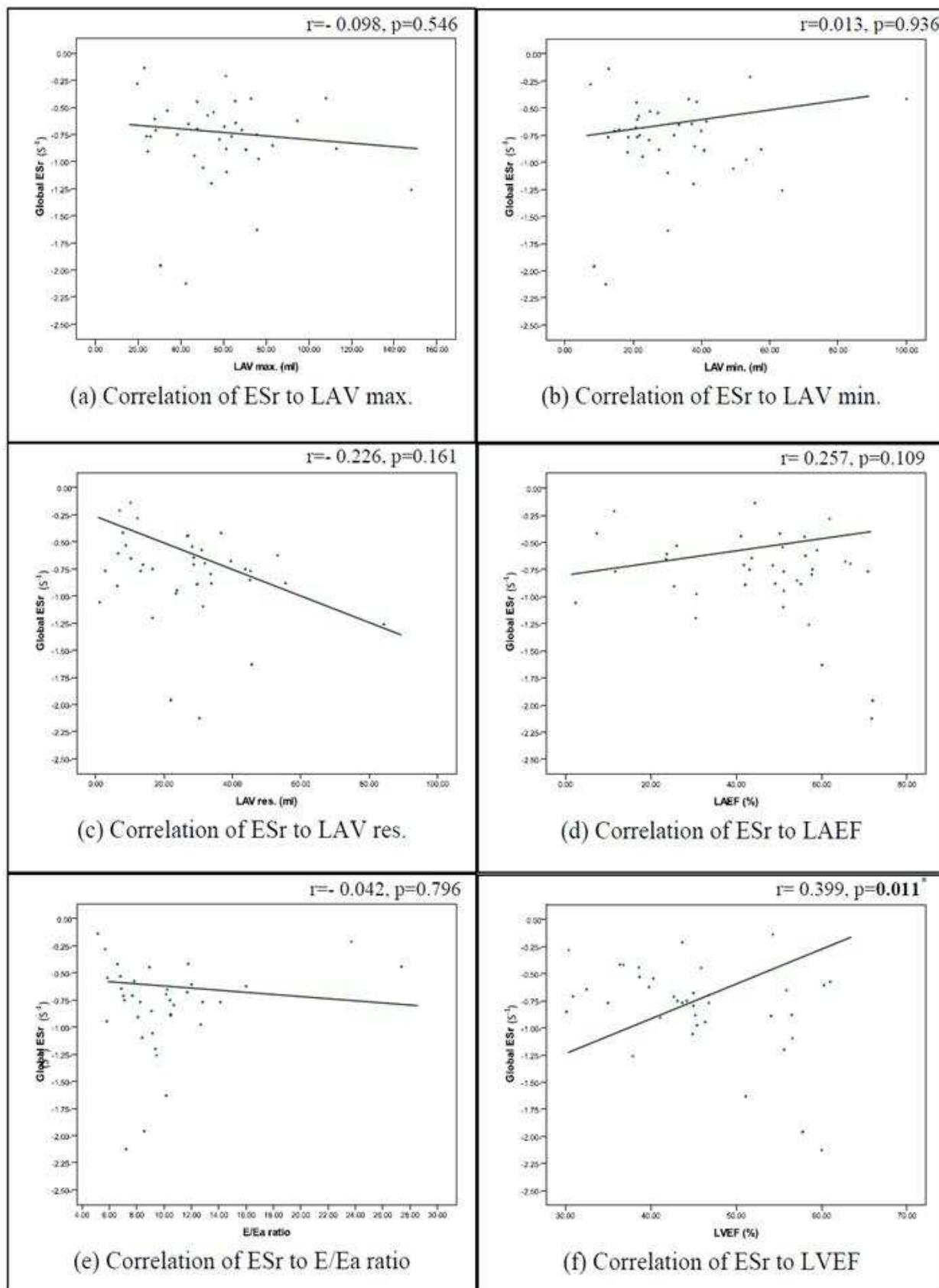
**Fig.61. Correlations of peak systolic strain to some echocardiographic parameters in patients with STEMI**



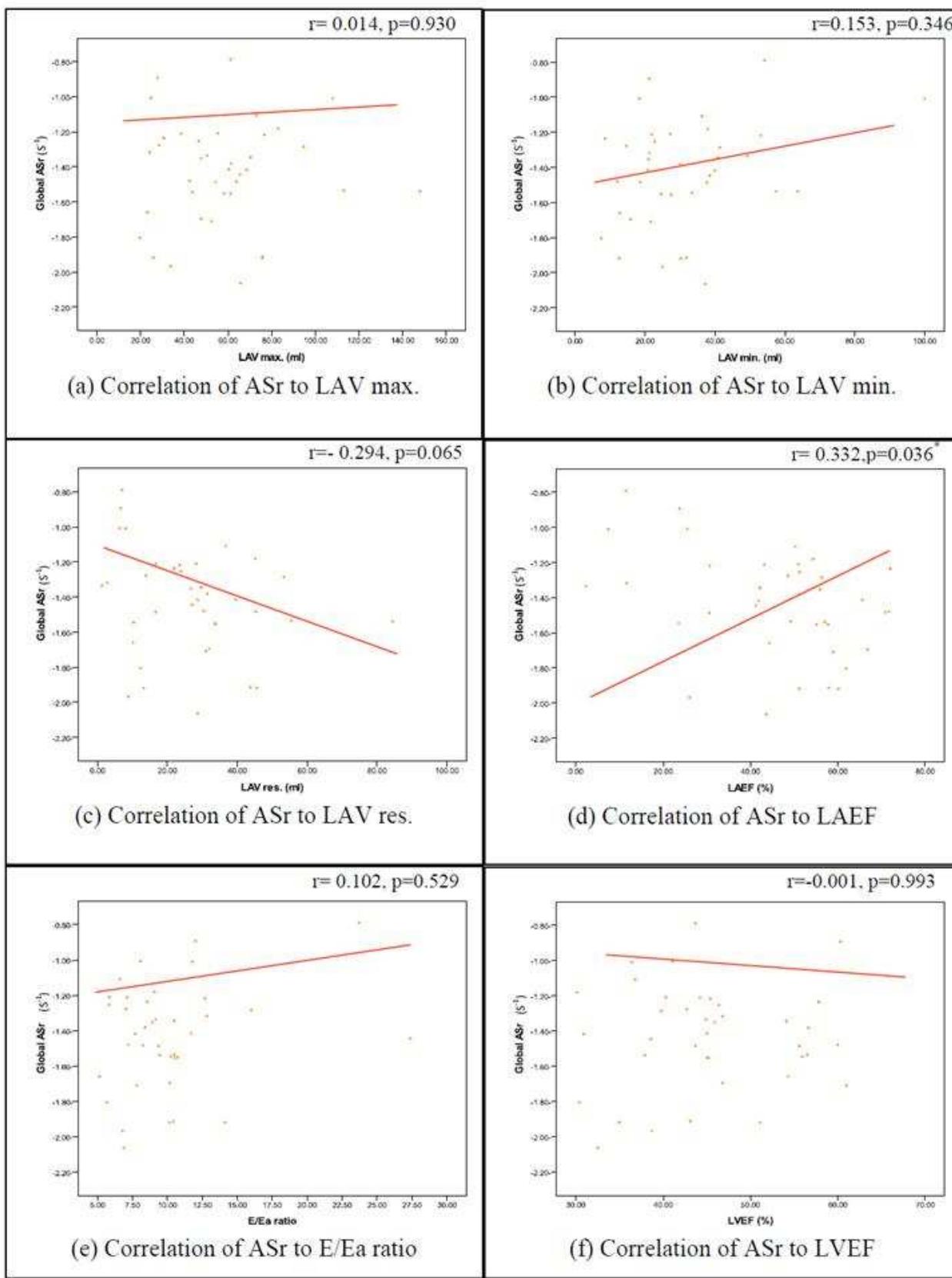
**Fig.62. Correlations of strain during left atrial contraction to some echocardiographic parameters in patients with STEMI**



**Fig. 63. Correlations of peak systolic strain rate to some echocardiographic parameters in patients with STEMI**



**Fig. 64. Correlations of early diastolic strain rate to some echocardiographic parameters in patients with STEMI**



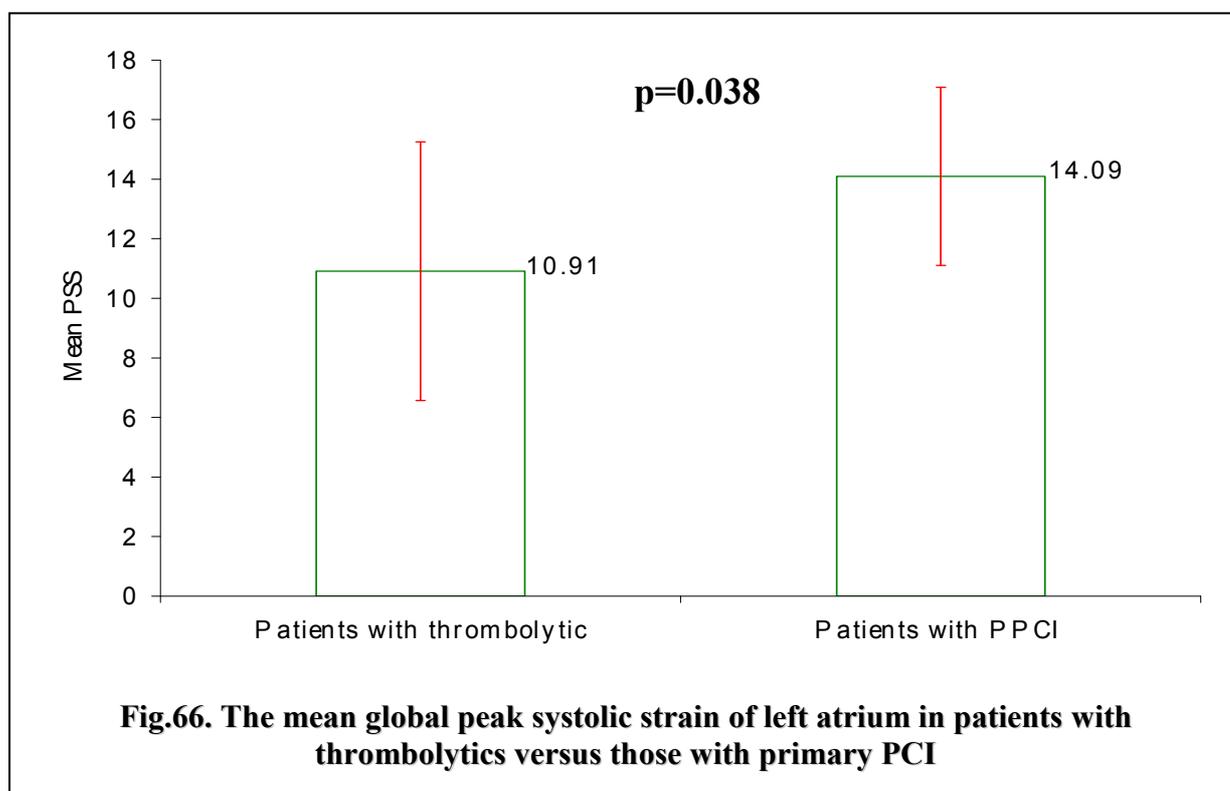
**Fig. 65. Correlations of late diastolic strain rate to some echocardiographic parameters in patients with STEMI**

**Comparison between the global PSS of left atrium in patients with thrombolytic or PPCI (Table 27 and Figure 66):**

When comparing the global PSS of left atrium between patients managed by thrombolytics and those by PPCI for reperfusion, it was found that a highly significant statistical difference existed between both groups ( $p= 0.038$ ). The mean value of patients managed by thrombolytics was significantly lower than in those managed by PPCI ( $10.91\pm 4.34$  vs.  $14.09\pm 2.99$ ).

**Table 27. Comparison between the global peak systolic strain of left atrium in patients with thrombolytic and primary percutaneous coronary intervention**

PSS (%)	Patients with thrombolytic (n=30)	Patients with PPCI (n=10)	p-value
Min. - Max.	2.21 – 20.49	10.62 – 20.51	<b>0.038*</b>
Mean ± SD	10.91 ± 4.34	14.09 ± 2.99	
Median	10.38	13.47	
PSS: peak systolic strain			
Student t- test for the difference between two means		*Statistically significant	



### **Relation of global peak systolic strain of left atrium to the site of infarction and coronary angiographic data in patients with myocardial infarction (Table 28, Figures 67 and 68)**

It was found that the mean value of the global peak systolic strain of left atrium for the inferior STEMI was (12.75±5.11%), for the anterior STEMI (10.80±4.04), for the anteroseptal STEMI was (12.19±2.72%) and for the anterolateral STEMI (11.43±4.29%), with statistically insignificant difference (p=0.704).

Regarding the relation of the global PSS to coronary angiographic data in the 38 patients who underwent coronary angiography, we found that the mean of global PSS in patients with single left anterior descending coronary artery disease (LAD) was (11.51±3.96%) and in those with single LCX disease it was (9.22±3.28%), while in single RCA disease it was (12.52±4.63%).

In those with two vessel disease, it was (9.63±4.48%) and in those of multivessel disease, it was (11.38±2.92%) with no significant statistical difference between them (p=0.696).

**Table 28. Relation of left atrial global peak systolic strain to the infarction site and coronary angiographic data**

Item	Global peak systolic strain (%)
Site of infarction: (n=40)	
- Inferior: (n =12 )	
Min. - Max.	5.27 - 20.49
Mean ± SD	<b>12.75 ± 5.11</b>
Median	11.78
- Anterior: (n = 14)	
Min. - Max.	2.21 - 16.64
Mean ± SD	<b>10.80 ± 4.04</b>
Median	10.53
- Anteroseptal: (n= 5)	
Min. - Max.	9.07 - 15.98
Mean ± SD	<b>12.19 ± 2.72</b>
Median	11.47
- Anterolateral: (n= 9)	
Min. - Max.	4.52 - 20.51
Mean ± SD	<b>11.43 ± 4.29</b>
Median	11.50
p = 0.704	
Coronary angiographic data: (n=38)	
- LAD disease: (n= 21)	
Min. - Max.	2.21 - 20.51
Mean ± SD	<b>11.51 ± 3.96</b>
Median	11.50
- LCX disease: (n=4)	
Min. - Max.	5.27 - 13.25
Mean ± SD	<b>9.22 ± 3.28</b>
Median	9.17
- RCA disease (n=5)	
Min. - Max.	8.14 - 20.36
Mean ± SD	<b>12.52 ± 4.63</b>
Median	11.43
- Two vessels disease: (n= 3)	
Min. - Max.	4.52 - 12.90
Mean ± SD	<b>9.63 ± 4.48</b>
Median	11.47
- Multi vessels disease: (n= 5)	
Min. - Max.	8.31 - 15.98
Mean ± SD	<b>11.38 ± 2.92</b>
Median	11.05
p = 0.696	
ANOVA for the difference between three or more means <span style="float: right;">*Statistically significant</span>	
LAD: left anterior descending coronary artery LCX: left circumflex coronary artery RCA: Right coronary artery	

