AIM OF THE WORK

To evaluate the diagnostic power of longitudinal 2D strain obtained by speckle tracking echocardiography in prediction of severe coronary artery disease in the resting echocardiogram.

PATIENTS

This is a prospective study that was carried from March 2013 to June 2014 on (60) patients referred to Alexandria University hospital for diagnostic coronary angiography with normal resting echocardiography they were enrolled in the study after obtaining their written informed consent, and approval of Ethics Committee of Alexandria University.

- **Based on the coronary angiography results, patients were grouped as follows:**
- **Group (A) twenty patients:** left main or three vessel coronary artery disease (high risk group).
- **Group (B) twenty patients:** one or two vessels coronary artery disease (low risk group).
- **Group (C) twenty persons:** no coronary artery disease (normal control group)

Exclusion criteria:

- Left ventricular systolic dysfunction with EF < 50%.
- Presence of regional wall motion abnormality at rest.
- Recent myocardial infarction.
- Arrhythmia; rapid atrial fibrillation, V.P.Cs(Ventricular premature contractions)
- Bundle branch block (B.B.B).
- Bad echocardiographic window.
- Significant valvular disease.

METHODS

In this prospective study all patients were subjected to:

1. Thorough history taking with special emphasis on:

- Nature of the chest pain including the onset and duration.
- Cardiovascular risk factors including: age, gender, current smoking, hypertension, diabetes mellitus, dyslipidemia, family history of coronary artery disease.

2. Clinical examination :

All the patients were submitted to full clinical evaluation on admission including; pulse, blood pressure and presence or absence of cardiac murmur, gallop or pulmonary congestion.

3. Electrocardiogram:

A standard 12 lead resting ECG was performed.

4. Coronary angiography:

Coronary angiography was performed using Toshiba infinix cardiac catheterization system with the use of specifically designed diagnostic catheters through percutaneous transfemoral approach. Lesion locations were be assessed and percent diameter stenosis was measured for each coronary lesion according to the American Heart Association classification, the number of affected vessels was assessed using a cutoff of percent diameter stenosis ≥ 70% for three epicardial vessels and ≥50% for left main coronary artery. High grade stenotic lesions (HSL) were defined as total or subtotal obstructions with antegrade TIMI flows of grade 0, 1, or 2. [56, 57]

5. Echocardiography:

Measurement of LVEDV (left ventricular end diastolic volume), LVESV (left ventricular end systolic volume) and EF (ejection fraction), by modified Simpson's method[55]

The 2D longitudinal peak systolic strain was performed using vivid q, General Electric Healthcare (GE Vingmed, Norway) equipped with a harmonic M4S variable-frequency (1.7-4 MHz) phased-array transducer.

All subjects were examined in the left lateral decubitus position according to the recommendations of the American Society of Echocardiography. [55]

Image Acquisition

Speckle tracking is an offline technique applied to that previously acquired 2D loops. The procedure started with loops obtained and recorded by using conventional 2-dimensional gray scale echocardiography during breath holding (to minimize through plane motion) with stable electrocardiographic tracing and an optimal ECG signal with a clear definition of the QRS-complex and P-wave ensuring a consistent ECG-triggering [58].

Three consecutive cardiac cycles were acquired from each of the three LV apical views; apical three chambers, apical four-chambers and apical two chambers views at a frame rate ranging 59–82 frame/s; mean 72+6 frame/s and digitally stored on a hard disk for post processing and off-line analysis.

An optimal quality in the 2D image was mandatory for a high quality recording.

Care was taken to obtain true apical views using standard anatomic landmarks in each view and to avoid fore-shortening of the analyzed myocardial structure, thus allowing a more reliable delineation of the endocardial border [59].

Post-processing and offline analysis

Recordings were processed by using automated function imaging (AFI) a specific acoustic-tracking software in the following sequence [60]:

1. For the left ventricle, because end-systole can be defined by aortic valve closure as seen in the apical long-axis view (3-chamber view), it was recommended to begin with analysis of this view to select the frame corresponding to the aortic valve closure, which is a useful reference for the subsequent analysis. If valve closure is difficult to recognize accurately (e.g., because of aortic sclerosis), a spectral Doppler display of LV outflow may be helpful.

2. Then the region of interest ROI was defined by manually tracing the endocardial surface of the myocardial segment in a still frame (default at end systole) in apical views by a point-and-click approach.

3. The ROI width and shape was set to match the myocardial thickness.

4. An epicardial surface tracing was then automatically generated by the system, thus creating (ROI) [59].

5. The software automatically divided the region of interest into 6 segments and the selected suitable natural acoustic markers (speckles) moving with the tissue for tracking.

6. Automated software program calculated frame-to frame displacement of speckles within ROI throughout the cardiac cycle.

Finally, the software automatically tracked and accepted segments of good tracking quality and rejected poorly tracked segments, while allowing the observer to manually override its decisions based on visual assessments of tracking quality.

Once ROI was optimized and performed in all 3 apical views, the software generated strain curves for each selected myocardial segment and from these curves, longitudinal strain was assessed in the 6 LV walls and the software algorithm automatically segmented the LV into 18 equidistant segments model in a 'bull's eye' plot, and each segment was individually analyzed. The average value of strain (%) at each segment (basal, mid, and apical) and global LV strain obtained from averaging the strain values of 18 LV segments were calculated and used for comparisons between the three groups. [61]

RESULTS

The present study was carried out on 60 adult patients of both sex that were grouped according to the coronary angiographic findings as follows; high-risk group with left main or three-vessel CAD (n=20), low-risk group with one- or two-vessel CAD (n=20), and normal group without CAD (n=20).

Demographic Characteristics

Age

The mean age was 59.15 ± 8.96 years in the high-risk group, 54.95 ± 7.81 years in the low-risk group, and 52.50 ± 5.50 years in the normal group. There was no significant difference between the high-risk and the low risk groups (p=0.233), or between the low-risk and the normal groups (p=0.595) regarding age, while there was a statistically significant difference between the high-risk group and the normal group regarding age (p=0.027) (Table 7, Figure 7).

Gender

Males constituted 15 patients (75%) of the high-risk group, 10 patients (50%) of the low-risk group, and 3 patients (15%) of normal group, while females constituted 5 patients (25%) of high-risk group, 10 patients (50%) of low-risk group, and 17 patients (85%) of normal group. with no statistically significant difference between the two groups regarding gender (p=0.251). There was no statistically significant difference between high-risk group and low-risk group regarding gender (p=0.12), while there was a statistically significant difference between high-risk group and normal group, also between low-risk group and normal group regarding gender (p<0.001, and p=0.018, respectively) (Table 7, Figure 8).

Table (7): Comparison between the three studied groups according to demographic data

	High Risk (n=20)		Low Risk (n=20)		Normal (n=20)		Total (n=60)	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Age (years)								
Min. – Max.	40.0 – 75.0		40.0 – 69.0		39.0 – 60.0		39.0 – 75.0	
Mean ± SD	59.15 ± 8.96		54.95 ± 7.81		52.50 ± 5.50		55.53 ± 7.93	
Median	59.0		54.0		53.0		55.0	
F(p)	3.955^{*} (0.025^{*})							
Sig .bet .grps	$^{Sch}p_1 = 0.233$, $^{Sch}p_2 = 0.027^{*}$, $^{Sch}p_3 = 0.595$							
Sex								
Male	15	75.0	10	50.0	3	15.0	28	46.7
Female	5	25.0	10	50.0	17	85.0	32	53.3
χ^2(p)	14.598^{*} (0.001^{*})							
Sig .bet .grps	$^{\chi^2}p_1 = 0.102$, $^{\chi^2}p_2 < 0.001^{*}$, $^{\chi^2}p_3 = 0.018^{*}$							

p: p value for comparing between three studied groups
F: F test (ANOVA)
Sig. bet. grps was done using Post Hoc test (Scheffe) test
χ^2: Chi square test
Sig. bet. grps was done using Chi square or Monte Carlo test
p_1: p value for comparing between high and low risk
p_2: p value for comparing between high and normal risk
p_3: p value for comparing between low and normal risk
*: Statistically significant at $p \leq 0.05$

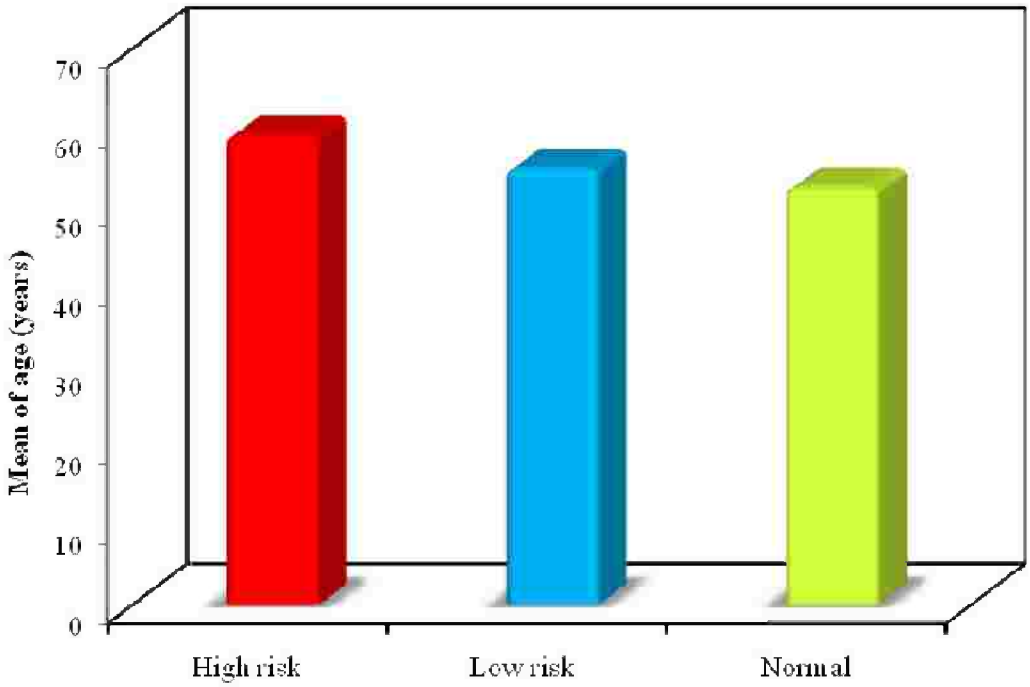


Figure (7): Comparison between the three studied groups according to age.

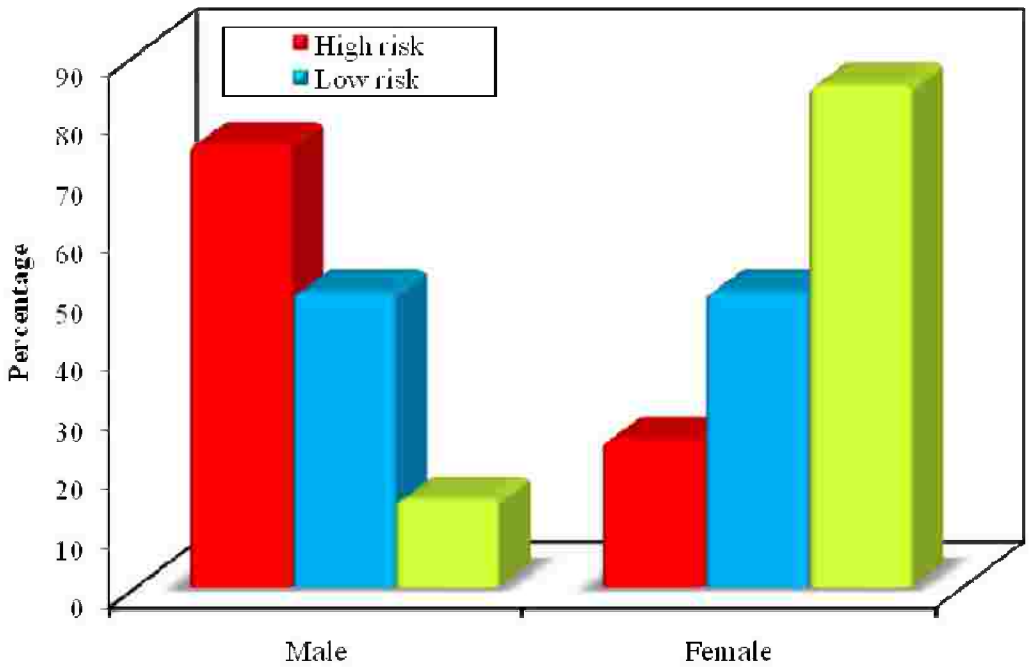


Figure (8): Comparison between the three studied groups according to gender.

Comparison between the Studied Groups Regarding Risk Factors

Hypertension was the commonest risk factor among the studied patients representing 14 patients (70%) of high-risk group, 11 patients (55%) of low-risk group, and 15 patients (75%) of the normal group with no significant difference between all groups (p=0.377) (Table 8, Figure 9).

There was no significant difference between high-risk and low risk groups or between low-risk and normal groups regarding diabetes mellitus (p=0.204, and p=0.127, respectively), while there was a significant difference between high-risk and normal groups regarding diabetes mellitus (p=0.002) (Table 8, Figure 9).

As regarding smoking, there was no significant difference between high-risk group and low risk group (p=0.749), while there was a significant difference between high-risk group and normal group, also between low-risk group and normal group (p=<0.001, and p=0.001, respectively) (Table 8, Figure 9).

As regarding dyslipidemia, there was a significant difference between high-risk and low-risk groups (p=0.027), also between high-risk and normal groups (p=<0.001), and between low-risk and normal groups (p=0.004) (Table 8, Figure 9).

Table (8): Comparison between the three studied groups according to risk factors

	High risk (n=20)		Low risk (n=20)		Normal (n=20)		Total (n=60)	
	No.	%	No.	%	No.	%	No.	%
Hypertension	14	70.0	11	55.0	15	75.0	40	66.7
χ^2(p)	1.950 (0.377)							
Diabetes	11	55.0	7	35.0	2	10.0	20	33.3
χ^2(p)	9.150* (0.010*)							
Sig .bet .grps	$\chi^2 p_1$= 0.204 , $\chi^2 p_2$=0.002*, $\chi^2 p_3$=0.127							
Smoking	12	60.0	11	55.0	1	5.0	24	40.0
χ^2(p)	15.417* (<0.001*)							
Sig .bet .grps	$\chi^2 p_1$=0.749 , $\chi^2 p_2$<0.001*, $\chi^2 p_3$=0.001*							
Dyslipidaemia	14	70.0	7	35.0	0	0.0	21	35.0
χ^2(p)	21.538* (<0.001*)							
Sig .bet .grps	$\chi^2 p_1$=0.027*, $\chi^2 p_2$<0.001*, $\chi^2 p_3$= 0.004*							

p: p value for comparing between three studied groups
χ^2: Chi square test
Sig. bet. grps was done using Chi square or Monte Carlo test
p_1: p value for comparing between high and low risk
p_2: p value for comparing between high and normal risk
p_3: p value for comparing between low and normal risk
*: Statistically significant at $p \leq 0.05$

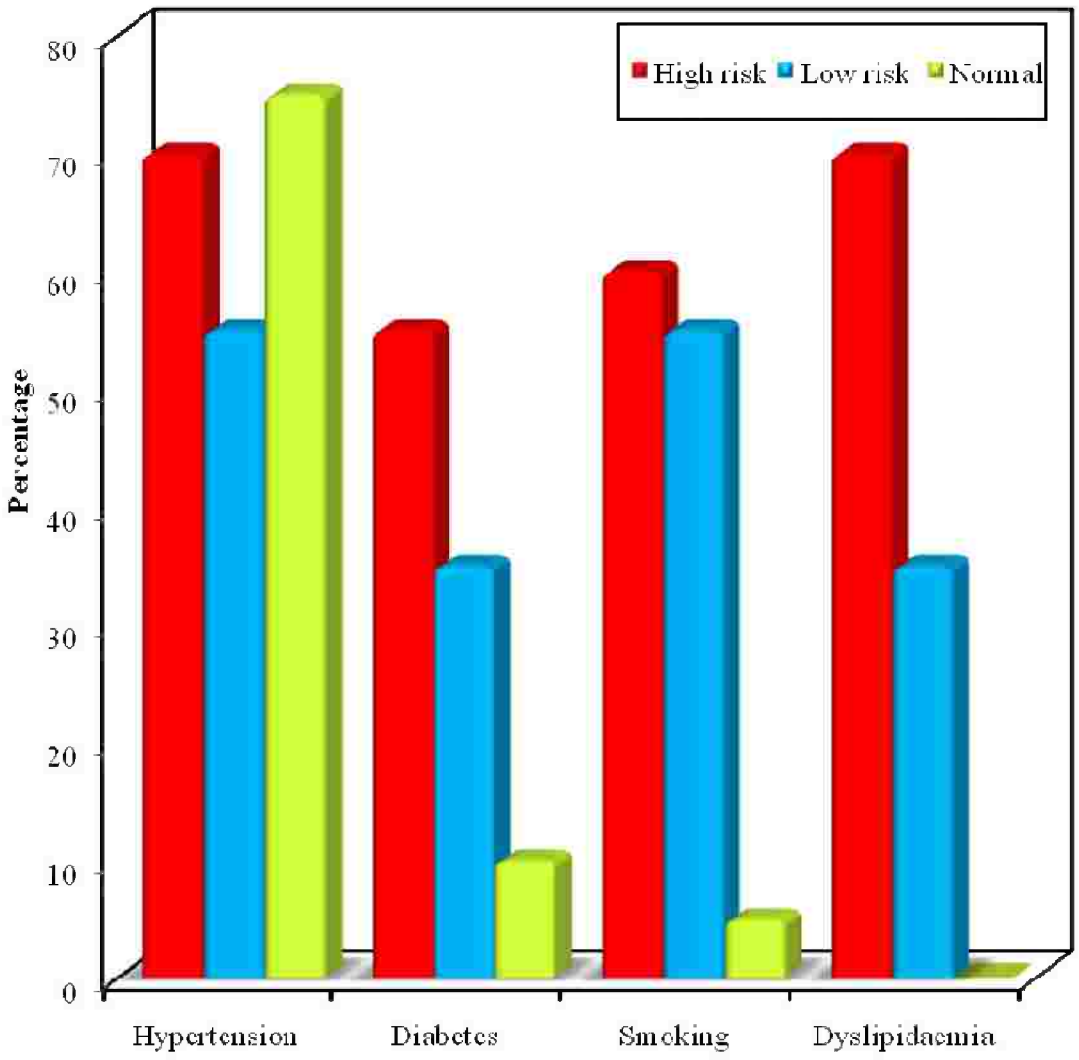


Figure (9): Comparison between the three studied groups according to risk factors.

Comparison between the Studied Groups According to Final Clinical Diagnosis

Table (9) and Figure (10) show the final clinical diagnosis of the studied group patients. In the high-risk group, 14 patients (70%) had stable angina while 6 patients (30%) had unstable angina. In the low risk group 17 patients (85%) had stable angina while 3 patients (15%) had unstable angina. All the normal group patients were diagnosed as having non-cardiac chest pain (100%).

Table (9): Comparison between the three studied groups according to clinical diagnosis.

	High risk (n=20)		Low risk (n=20)		Normal (n=20)		Total (n=60)	
	No.	%	No.	%	No.	%	No.	%
Stable angina	14	70.0	17	85.0	0	0.0	31	51.7
χ^2(p)	$32.970^*(<0.001^*)$							
Sig .bet .grps	$\chi^2p_1= 0.451$, $\chi^2p_2<0.001^*$, $\chi^2p_3<0.001^*$							
Unstable angina	6	30.0	3	15.0	0	0.0	9	15.0
χ^2(^{MC}p)	7.059^* (0.029^*)							
Sig .bet .grps	$\chi^2p_1=0.451$, $\chi^2p_2= 0.008^*$, $\chi^2p_3= 0.072$							
Non - cardiac chest pain	0	0.0	0	0.0	20	100.0	20	33.3
χ^2(p)	$60.000^*(<0.001^*)$							
Sig .bet .grps	$\chi^2p_1= -$, $\chi^2p_2<0.001^*$, $\chi^2p_3<0.001^*$							

p: p value for comparing between three studied groups
χ^2: Chi square test
MC: Monte Carlo test
Sig. bet. grps was done using Chi square or Monte Carlo test
p_1: p value for comparing between high and low risk
p_2: p value for comparing between high and normal risk
p_3: p value for comparing between low and normal risk
*: Statistically significant at $p \leq 0.05$

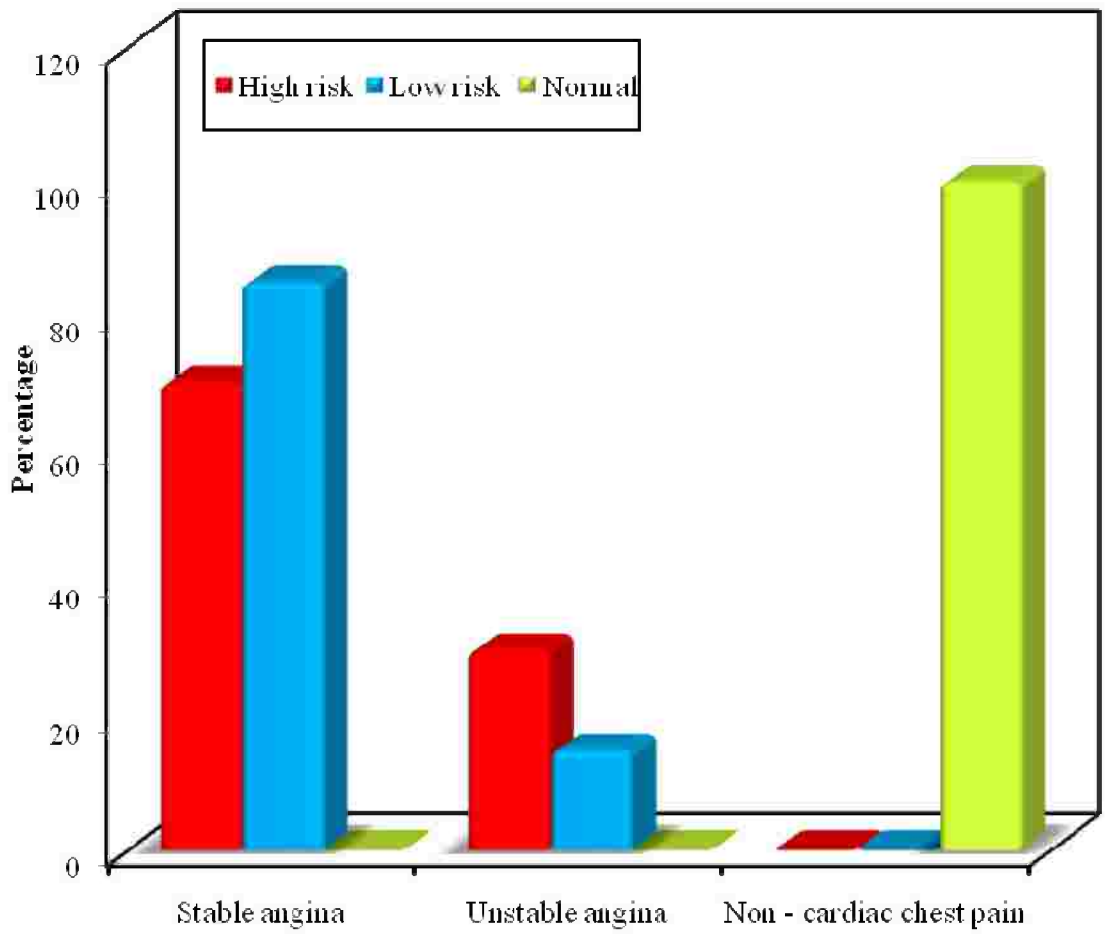


Figure (10): Comparison between the three studied groups according to final clinical diagnosis.

Comparison between the Studied Groups According to Coronary Angiographic Data

The coronary angiographic data of the studied groups is presented in table (10) and the number of high stenotic lesions (HSLs) is presented in table (11).

The LMCA was the diseased vessel in 6 patients (30%) of the high-risk group, while no patients from the low-risk group had a diseased LMCA. The LAD, LCX, and RCA were the diseased vessels in 19 (95%), 19 (95%), and 18 patients (90%) of the high-risk group, respectively, while they were the diseased vessels in 7 (35%), 17 (85%), and 10 patients (35%) of the low-risk group, respectively (Figure 11).

There was a significant difference between the high-risk group and low-risk group according to the number of patients with diseased LMCA, LCX, and RCA in favor of the high-risk group ($p=0.02$, $p<0.001$, and $p<0.001$, respectively), while there was no significant difference between both groups according to the number of patients with diseased LAD ($p=0.605$).

As regarding the number of HSLs, in the high-risk group; 6 patients (30%) had single HSL, and 9 patients (45%) had two HSLs, while in the low-risk group; 10 patients (50%) had single HSL, and 1 patient (5%) had 2 HSLs. Only 1 patient (5%) from the high-risk group had 3 HSLs while no patients from the low-risk group had 3 HSLs (Figure 12).

Table (10): Comparison between the studied groups according to coronary angiographic data.

	High risk (n=20)		Low risk (n=20)		Total (n=60)		χ^2	p
	No.	%	No.	%	No.	%		
LMCA	6	30.0	0	0.0	6	10.0	9.382*	$^{FE}p = 0.020^*$
RCA	18	90.0	7	35.0	25	41.7	12.907*	<0.001*
LAD	19	95.0	17	85.0	36	60.0	1.111	$^{FE}p = 0.605$
LCX	19	95.0	2	10.0	21	35.0	28.972*	<0.001*

p: p value for comparing between three studied groups
χ^2: Chi square test
FE: Fisher Exact test
*: Statistically significant at $p \leq 0.05$

Table (11): Comparison between the studied groups according to number of HSL.

	High risk (n=20)		Low risk (n=20)		Total (n=60)		χ^2	p
	No.	%	No.	%	No.	%		
1 HSL	6	30.0	10	50.0	16	26.7	1.667	0.197
2 HSL	9	45.0	1	5.0	10	16.7	8.533*	0.003*
3 HSL	1	5.0	0	0.0	1	1.7	1.026	$^{FE}p = 1.000$

HSL, high stenotic lesion.
χ^2: Chi square test
FE: Fisher Exact test
*: Statistically significant at $p \leq 0.05$

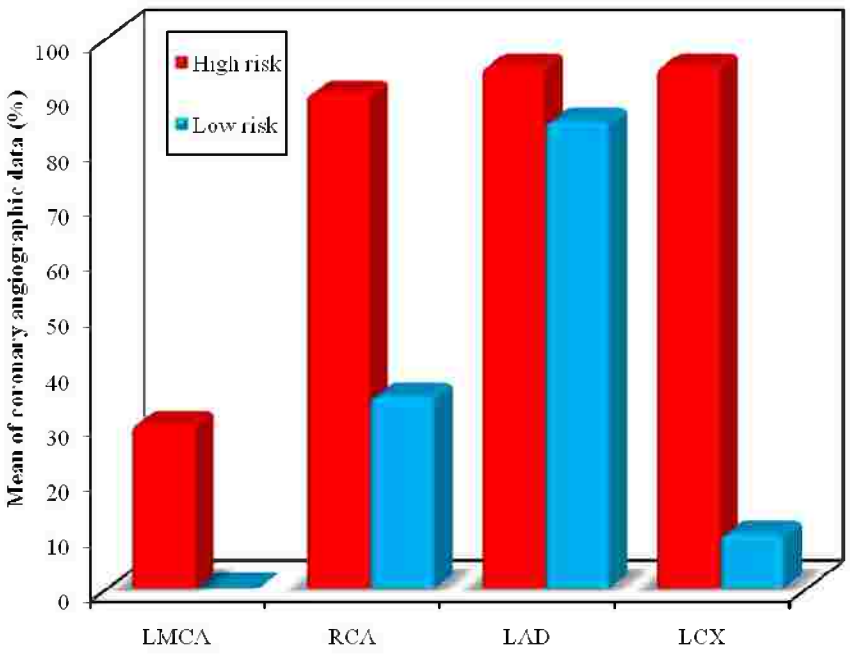


Figure (11): Comparison between high-risk group and low-risk group according to coronary angiographic data.

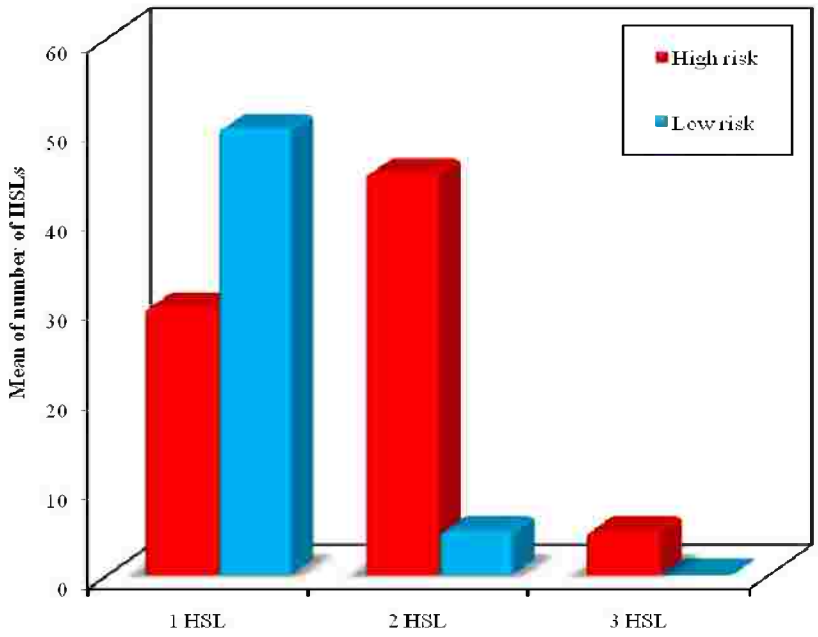


Figure (12): Comparison between high-risk group and low-risk group according to number of high stenotic lesions.

Comparison between the Studied Groups According to Echocardiographic Parameters Including Strain Values

Table (12) shows the echocardiographic parameters and the strain values of the studied groups. There was no significant difference between the studied groups regarding LV end diastolic volume, LV end systolic volume, LV ejection fraction, and AVC (p=0.29, p=0,319, p=0.96, and p=0.777, respectively).

As regarding the strain patterns of the studied groups, the mean values of the global peak systolic longitudinal strain (apical three chamber view) were -14.62 ± 2.30% in the high-risk group, -18.50 ± 2.16% in the low-risk group, and -20.83 ± 2.33% in the normal group. There was a significant difference between the high-risk group and low-risk group (p<0.001), also between the high-risk group and the normal group (p<0.001), and between the low-risk group and the normal group (p=0.008) (Table 12, Figure 13-14).

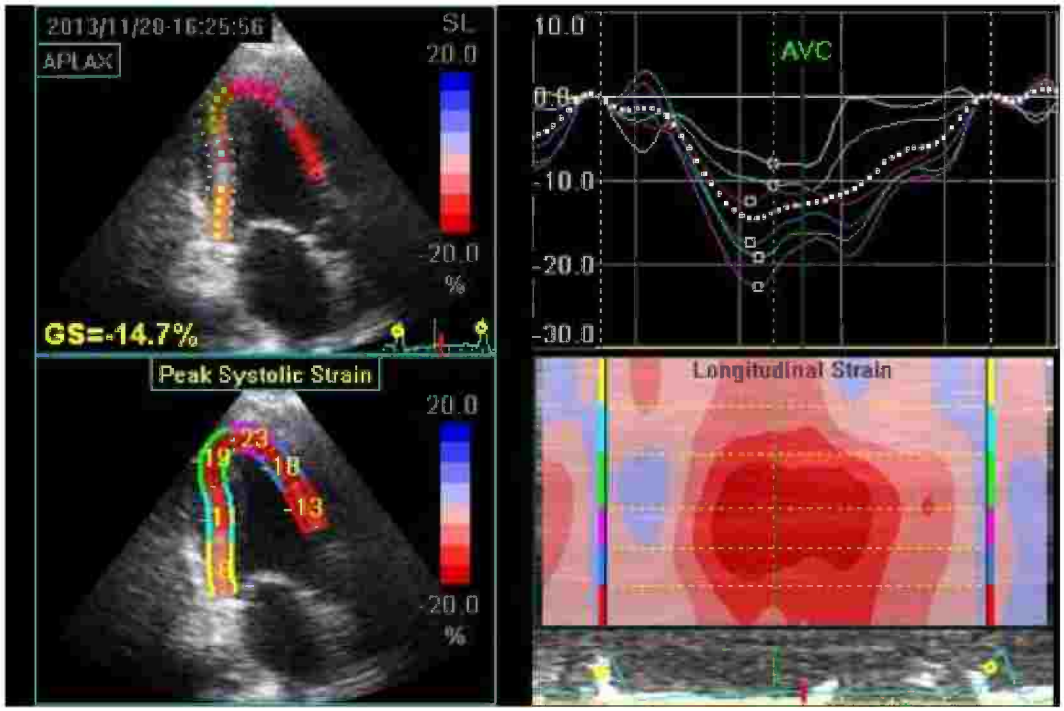
The mean values of the global peak systolic longitudinal strain (apical 4 chamber view) were -16.20 ± 2.86% in the high-risk group, -19.35 ± 2.63% in the low-risk group, and -21.52 ± 2.48% in the normal group. There was a significant difference between the high-risk group and low-risk group (p=0.002), also between the high-risk group and the normal group (p<0.001), and between the low-risk group and the normal group (p=0.044) (Table 12, Figure 15-16).

The mean values of the global peak systolic longitudinal strain (apical 2 chamber view) were -15.14 ± 2.70% in the high-risk group, -19.04 ± 2.44% in the low-risk group, and -22.55 ± 3.57% in the normal group. There was a significant difference between the high-risk group and low-risk group (p=0.002), also between the high-risk group and the normal group (p<0.001), and between the low-risk group and the normal group (p=0.002) (Table 12, Figure17).

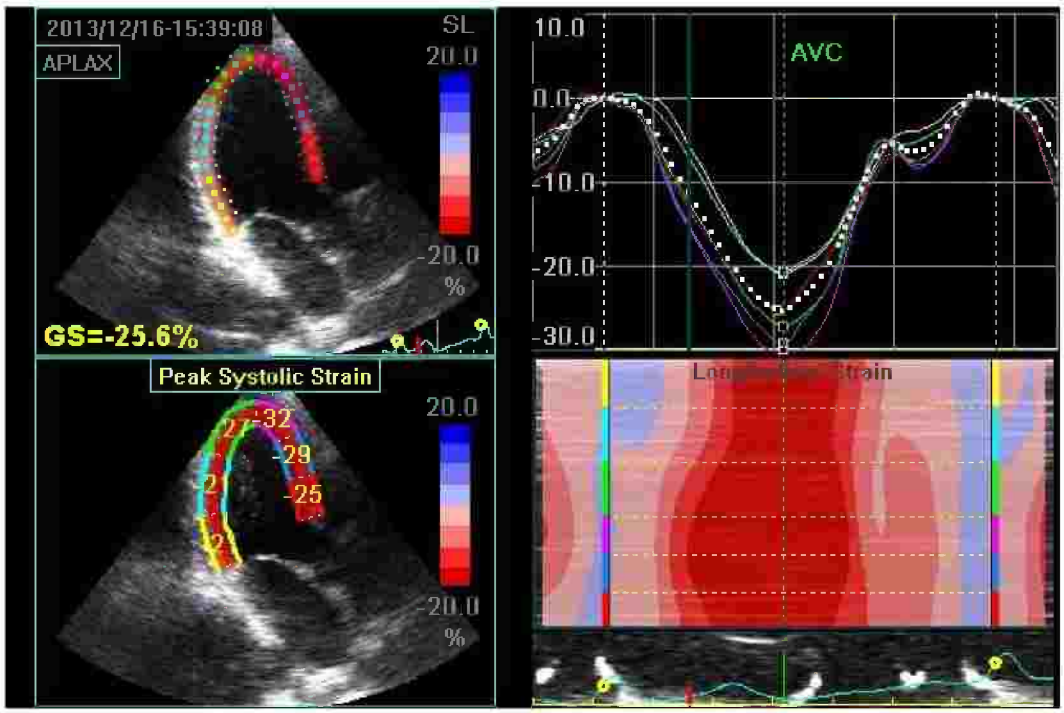
Table (12): Comparison between the three studied groups according to echocardiographic parameters including strain values.

	High risk (n=20)	Low risk (n=20)	Normal (n=20)	Total (n=60)
LV end diastolic volume (ml)				
Min. – Max.	70.0 - 177.0	69.0 - 147.0	70.0 - 132.0	69.0 - 177.0
Mean ± SD	108.8 ± 29.6	99.95 ± 24.68	96.90 ± 18.07	101.88 ± 24.70
Median	112.50	93.0	93.50	96.0
F(p)	1.264 (0.290)			
LV end systolic volume (ml)				
Min. – Max.	26.0 - 70.0	23.0 - 62.0	25.0 - 52.0	23.0 - 70.0
Mean ± SD	42.60 ± 12.10	39.10 ± 10.76	37.80 ± 7.40	39.83 ± 10.31
Median	40.50	36.0	37.50	37.0
F(p)	1.166 (0.319)			
LV ejection fraction (%)				
Min. – Max.	57.0 - 69.0	55.0 - 66.0	57.0 - 67.0	55.0 - 69.0
Mean ± SD	61.40 ± 3.38	61.15 ± 2.72	61.20 ± 2.63	61.25 ± 2.88
Median	60.50	61.0	60.50	61.0
F(p)	0.041 (0.960)			
AVC				
Min. – Max.	269.0 - 448.0	261.0 - 441.0	274.0 - 613.0	261.0 - 613.0
Mean ± SD	352.95 ± 49.4	364.4 ± 44.26	362.2 ± 65.36	359.82 ± 53.06
Median	345.0	359.0	359.0	356.50
F(p)	0.253 (0.777)			
G peak SL (A3C) (%)				
Min. – Max.	-18.60 - -9.00	-22.9 - -14.30	-25.6 - -17.30	-25.60 - -9.0
Mean ± SD	-14.62 ± 2.30	-18.50 ± 2.16	-20.83 ± 2.33	-17.98 ± 3.41
Median	-15.05	-18.40	-20.50	-18.10
F(p)	38.292^{*} ($<0.001^{*}$)			
Sig .bet .grps	$^{Sch}p_1<0.001^{*}$, $^{Sch}p_2<0.001^{*}$, $^{Sch}p_3=0.008^{*}$			
G peak SL (A4C) (%)				
Min. – Max.	-20.9 - -11.20	-25.6 - -16.10	-25.7 - -17.70	-25.70 - -11.20
Mean ± SD	-16.20 ± 2.86	-19.35 ± 2.63	-21.52 ± 2.48	-19.02 ± 3.42
Median	-16.30	-18.95	-21.0	-18.95
F(p)	20.165^{*} ($<0.001^{*}$)			
Sig .bet .grps	$^{Sch}p_1=0.002^{*}$, $^{Sch}p_2<0.001^{*}$, $^{Sch}p_3=0.044^{*}$			
G peak SL (A2C) (%)				
Min. – Max.	-18.2 - -10.10	-23.3 - -13.60	-31.6 - -18.60	-31.60 - -10.10
Mean ± SD	-15.14 ± 2.70	-19.04 ± 2.44	-22.55 ± 3.57	-18.91 ± 4.21
Median	-15.80	-18.90	-21.70	-18.70
F(p)	31.784^{*} ($<0.001^{*}$)			
Sig .bet .grps	$^{Sch}p_1=0.002^{*}$, $^{Sch}p_2<0.001^{*}$, $^{Sch}p_3=0.002^{*}$			

p: p value for comparing between three studied groups
F: F test (ANOVA)
Sig. bet. grps was done using Post Hoc test (Scheffe) test
p_1: p value for comparing between high and low risk
p_2: p value for comparing between high and normal risk
p_3: p value for comparing between low and normal risk
*: Statistically significant at $p \leq 0.05$



A



B

Figure (13): Comparison of 2D STE measurement of longitudinal systolic strain in apical 3-ch view between case A from the high risk group and case B from the normal group. AVC: aortic valve closure, GS: global strain

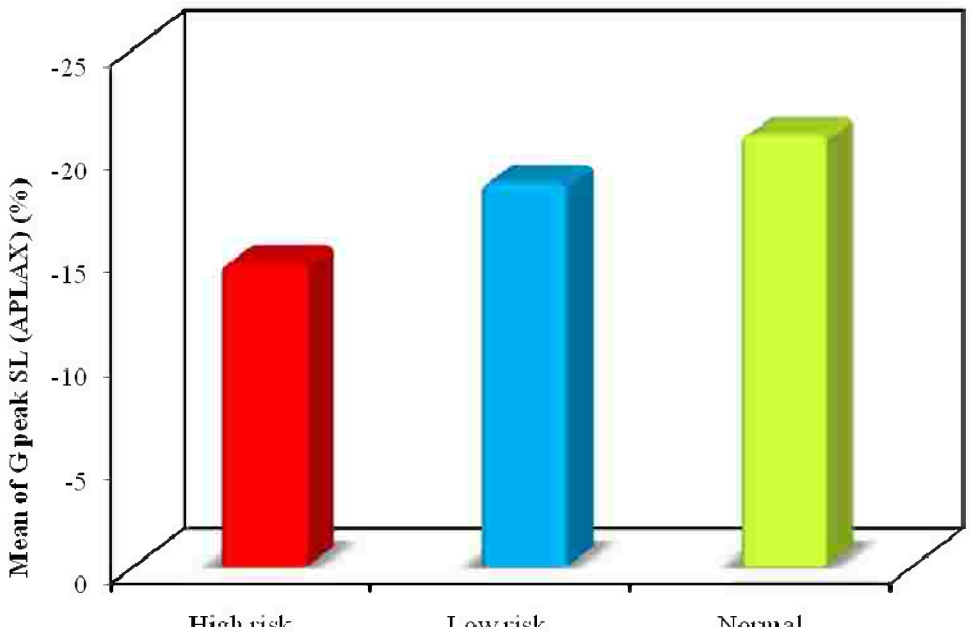


Figure (14): Comparison between the three studied groups according to G peak SL (A3C).

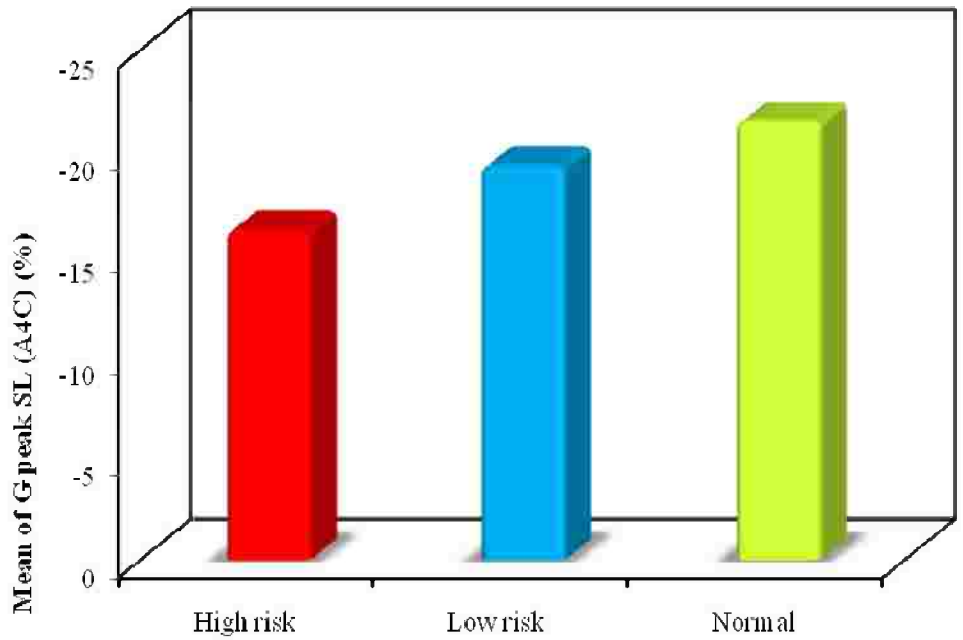
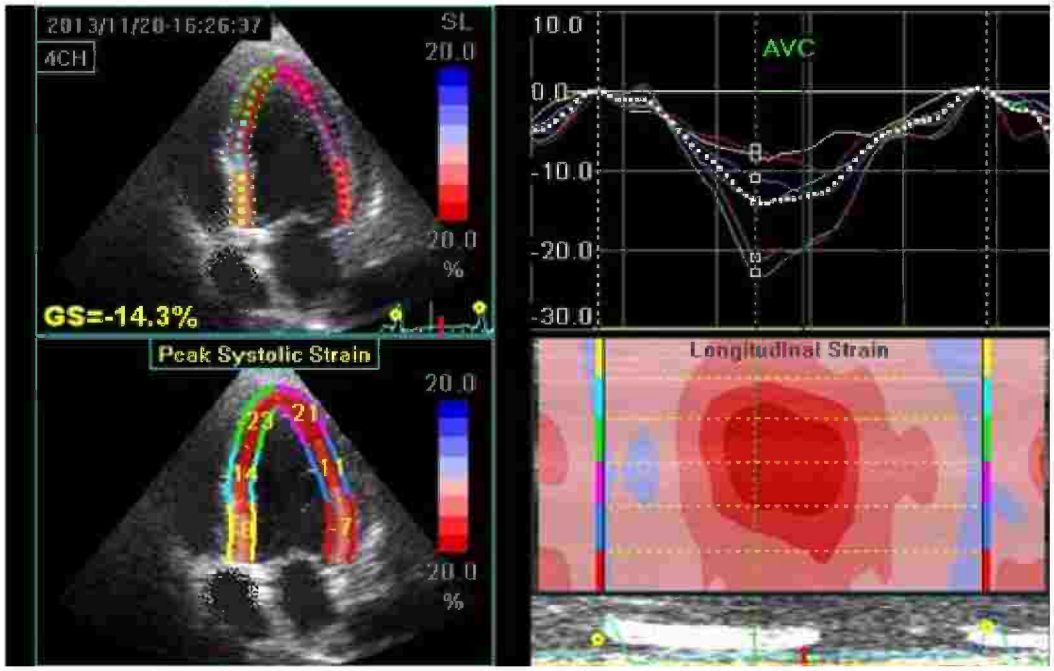
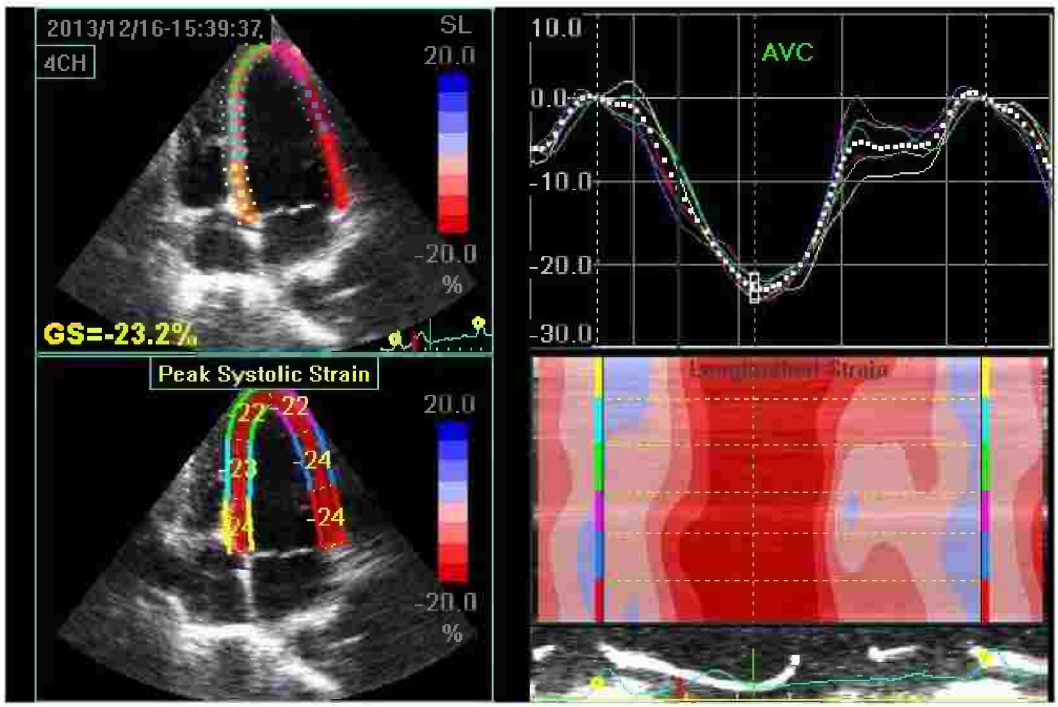


Figure (15): Comparison between the three studied groups according to G peak SL (A4C).



A



B

Figure (16): Comparison of 2D STE measurement of longitudinal systolic strain in apical 4-ch view between case A from the high risk group and case B from the normal group. AVC: aortic valve closer, GS: global strain

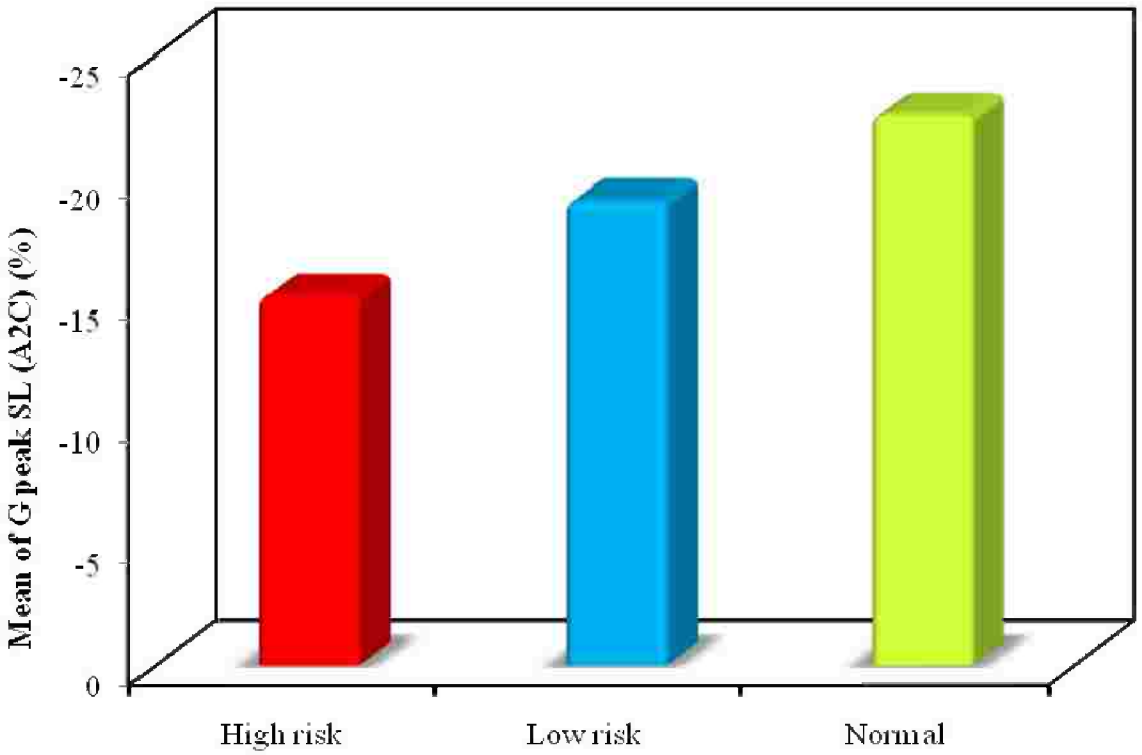


Figure (17): Comparison between the three studied groups according to G peak SL (A2C).

Comparison between the Studied Groups According to Global and Segmental Peak Systolic Longitudinal Strains

Global and segmental peak systolic longitudinal strains (PSLSs) in the three study groups are presented in Table (13) and Figures (18-24). Global and segmental PSLSs were lower in the high-risk group than in the other two groups. There was a statistically significant difference between the three studied groups regarding global PSLS ($p<0.001$), basal PSLS ($p<0.001$), mid PSLS ($p<0.001$), apical PSLS ($p<0.001$), also Basal and Mid PSLS ($p<0.001$).

Table (13): Comparison between the three studied groups according to global and segmental peak systolic longitudinal strains.

	High risk (n=20)	Low risk (n=20)	Normal (n=20)	Total (n=60)
Global peak SL (AVG) - %				
Min. – Max.	-18.9 - -10.50	-22.5 - -15.80	-26.4 - -18.50	-26.40 - -10.50
Mean ± SD	-15.33 ± 2.39	-18.98 ± 1.60	-21.62 ± 2.44	-18.64 ± 3.37
Median	-15.90	-18.65	-21.30	-18.60
F(p)	42.074* (<0.001*)			
Sig .bet .grps	$^{Sch}p_1$<0.001, $^{Sch}p_2$<0.001*, $^{Sch}p_3$= 0.001*			
Basal PSLS				
Min. – Max.	-17.8 - - 9.33	-19.50 - -12.67	-24.83 - -16.83	-24.83 - -9.33
Mean ± SD	-13.47 ± 2.19	-15.88 ± 1.89	-20.58 ± 2.50	-16.64 ± 3.69
Median	-13.75	-15.92	-20.50	-16.08
F(p)	53.798* (<0.001*)			
Sig .bet .grps	$^{Sch}p_1$= 0.004*, $^{Sch}p_2$<0.001*, $^{Sch}p_3$<0.001*			
Mid PSLS				
Min. – Max.	-18.17 - -10.17	-21.83 - -15.50	-26.17 - -17.83	-26.17 - -10.17
Mean ± SD	-14.78 ± 2.19	-18.27 ± 1.63	-21.43 ± 2.46	-18.16 ± 3.44
Median	-15.58	-18.0	-21.42	-18.00
F(p)	49.084* (<0.001*)			
Sig .bet .grps	$^{Sch}p_1$<0.001*, $^{Sch}p_2$<0.001*, $^{Sch}p_3$<0.001*			
Apical PSLS				
Min. – Max.	-22.83 - -7.17	-31.50 - -18.17	-29.33 - -15.33	-31.50 - -7.17
Mean ± SD	-17.70 ± 4.46	-22.79 ± 3.39	-22.69 ± 3.65	-21.06 ± 4.49
Median	-18.17	-22.08	-22.83	-21.17
F(p)	11.364* (<0.001*)			
Sig .bet .grps	$^{Sch}p_1$=0.001*, $^{Sch}p_2$=0.001*, $^{Sch}p_3$=0.997			
Basal and Mid PSLS				
Min. – Max.	-18.0 - -9.75	-20.67 - -14.17	-25.0 - -17.67	-25.0 - -9.75
Mean ± SD	-14.12 ± 2.05	-17.08 ± 1.52	-21.0 ± 2.37	-17.40 ± 3.46
Median	-14.63	-16.83	-20.33	-17.0
F(p)	59.007* (<0.001*)			
Sig .bet .grps	$^{Sch}p_1$<0.001*, $^{Sch}p_2$<0.001*, $^{Sch}p_3$<0.001*			

p: p value for comparing between three studied groups
F: F test (ANOVA)
Sig. bet. grps was done using Post Hoc test (Scheffe) test
p_1: p value for comparing between high and low risk
p_2: p value for comparing between high and normal risk
p_3: p value for comparing between low and normal risk
*: Statistically significant at $p \leq 0.05$

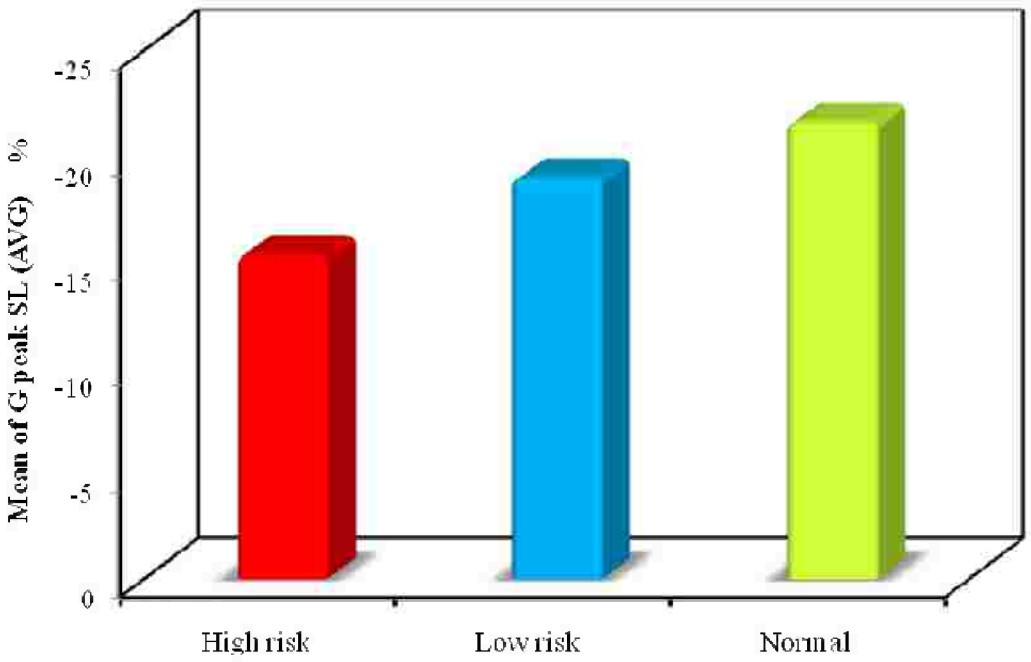


Figure (18): Comparison between the three studied groups according to global peak systolic longitudinal strain.

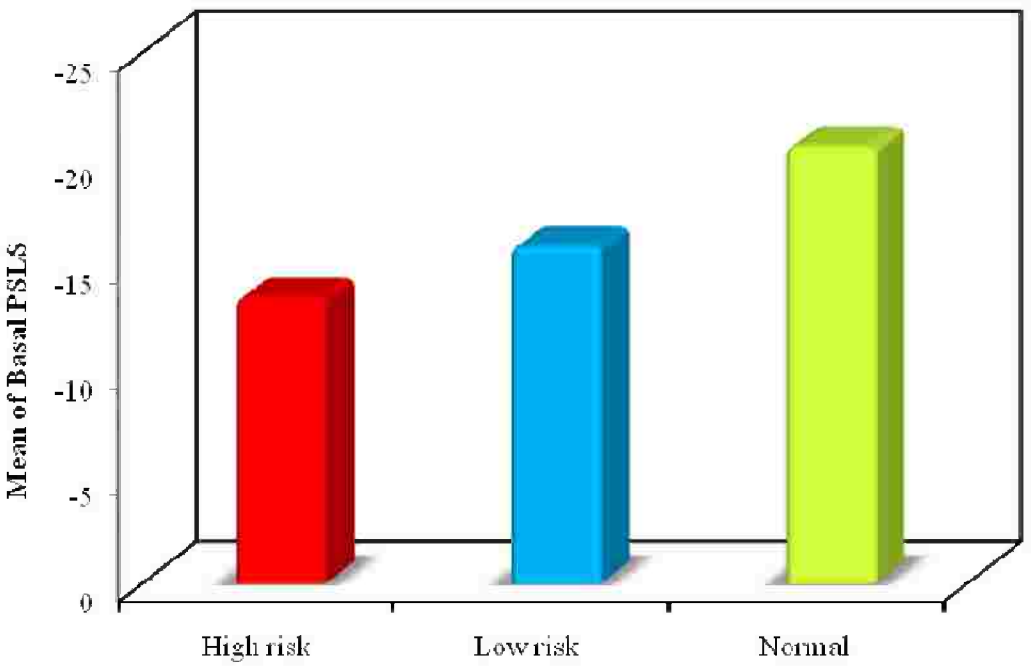


Figure (19): Comparison between the three studied groups according to basal peak systolic longitudinal strain.

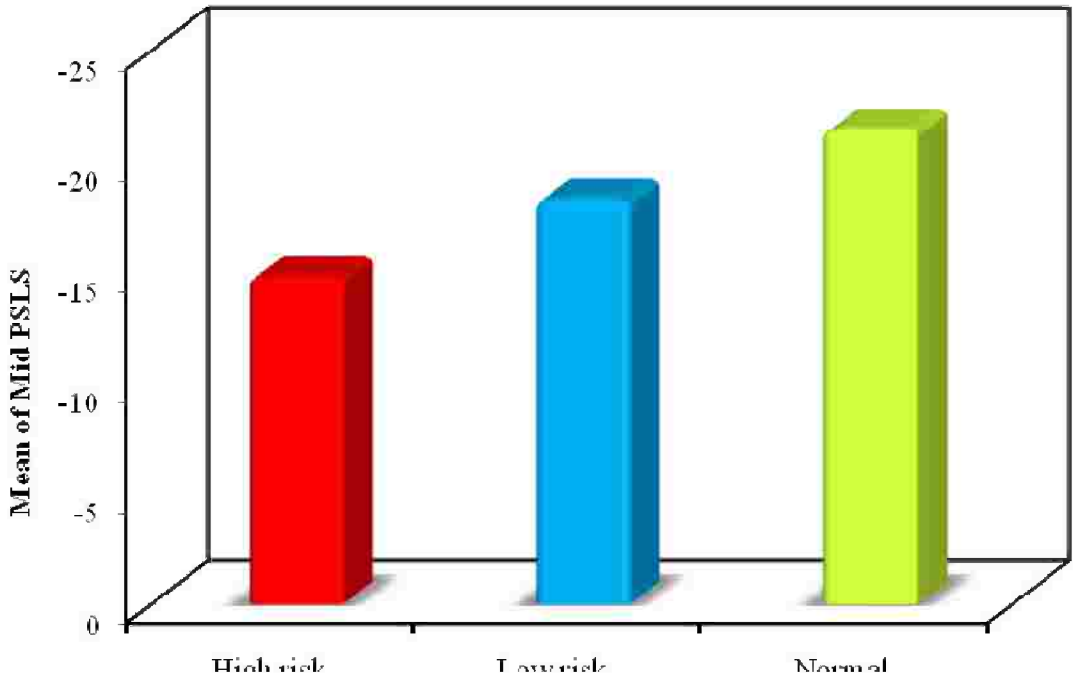


Figure (20): Comparison between the three studied groups according to mid peak systolic longitudinal strain.

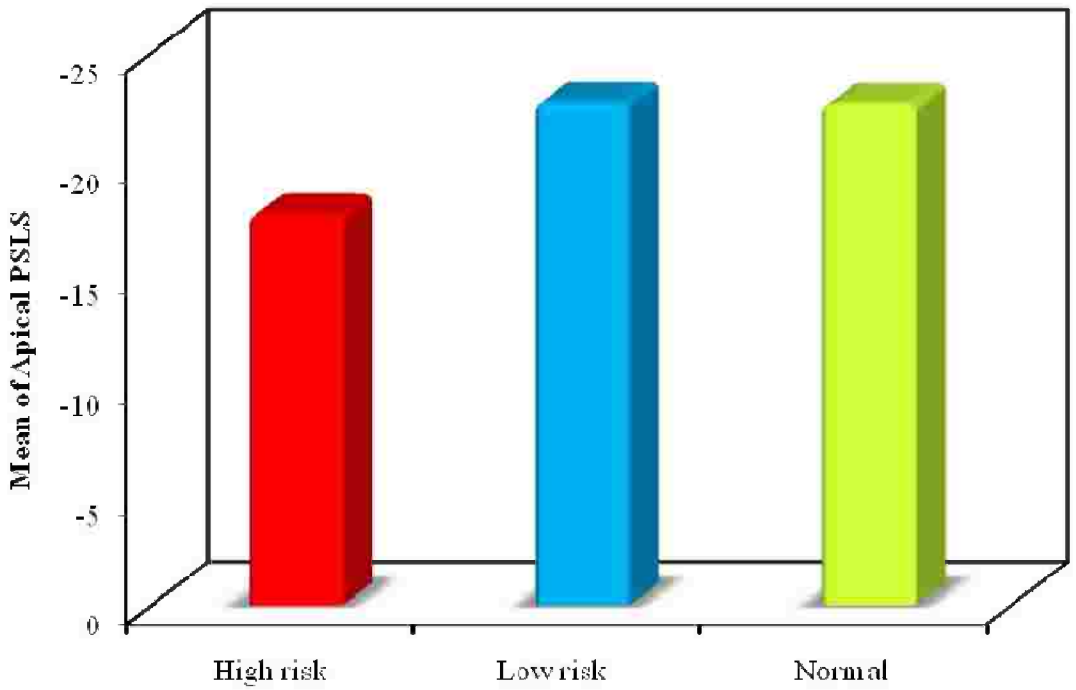


Figure (21): Comparison between the three studied groups according to apical peak systolic longitudinal strain.

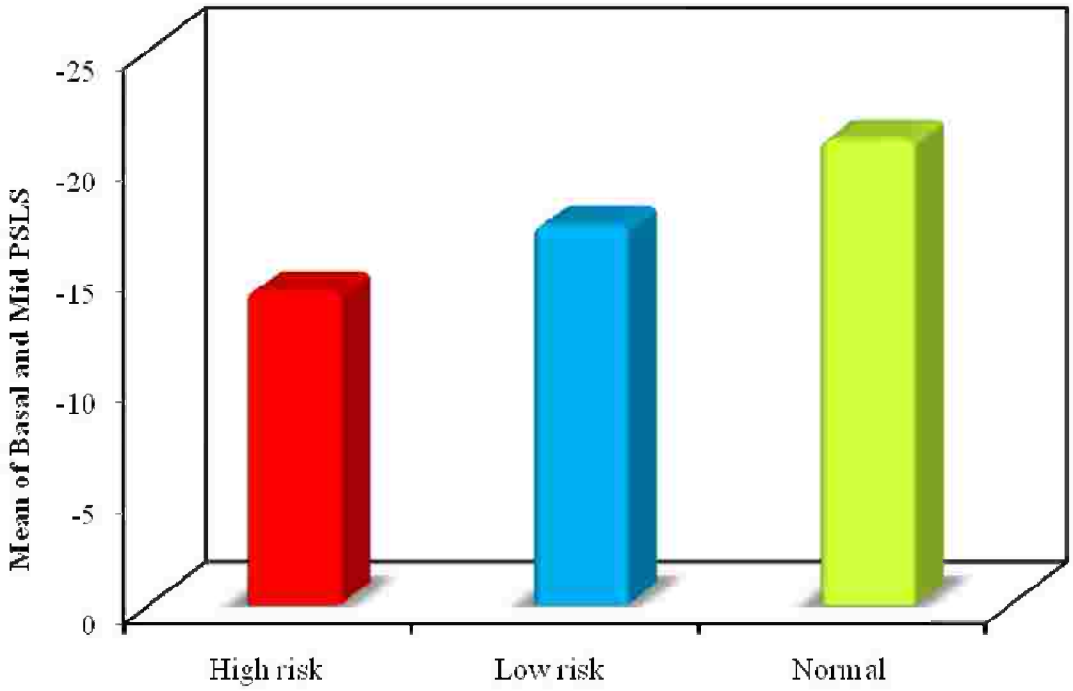
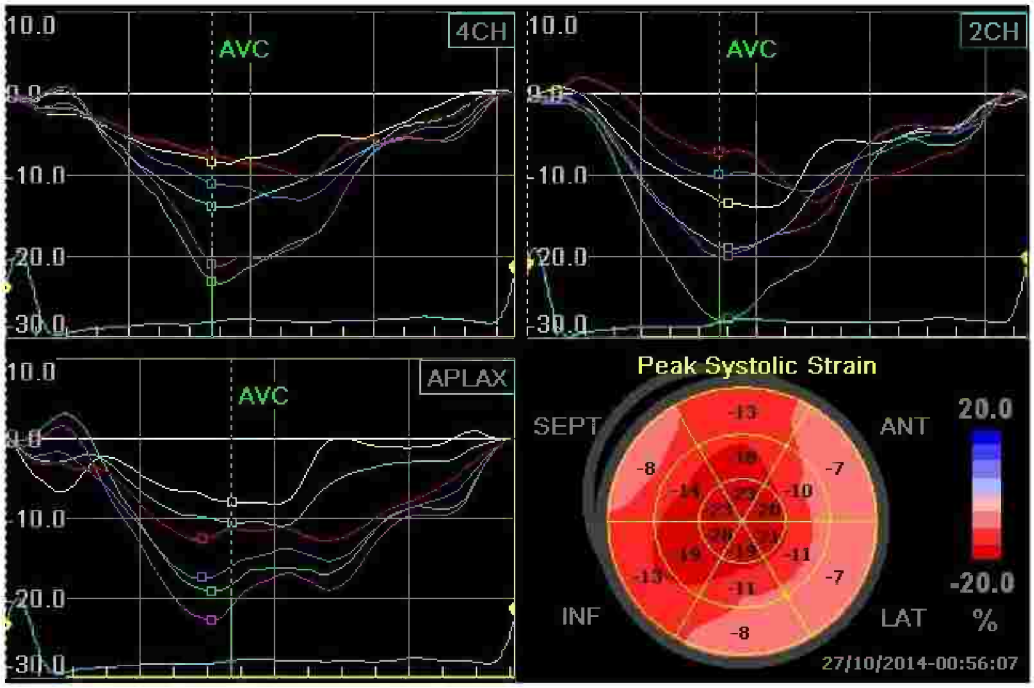
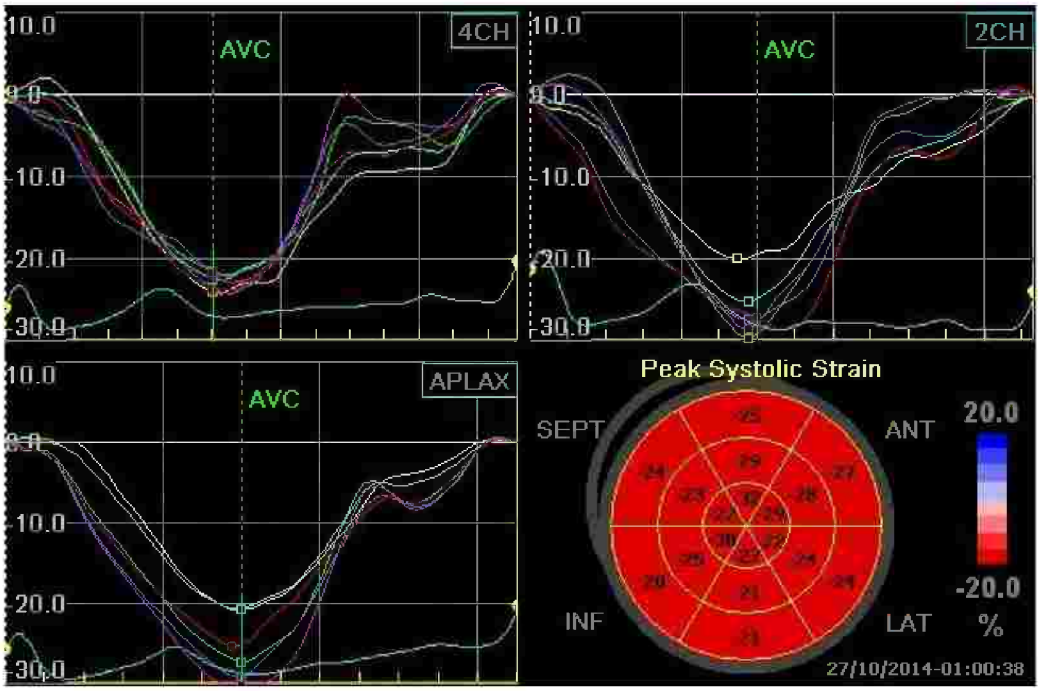


Figure (22): Comparison between the three studied groups according to basal and mid peak systolic longitudinal strain.

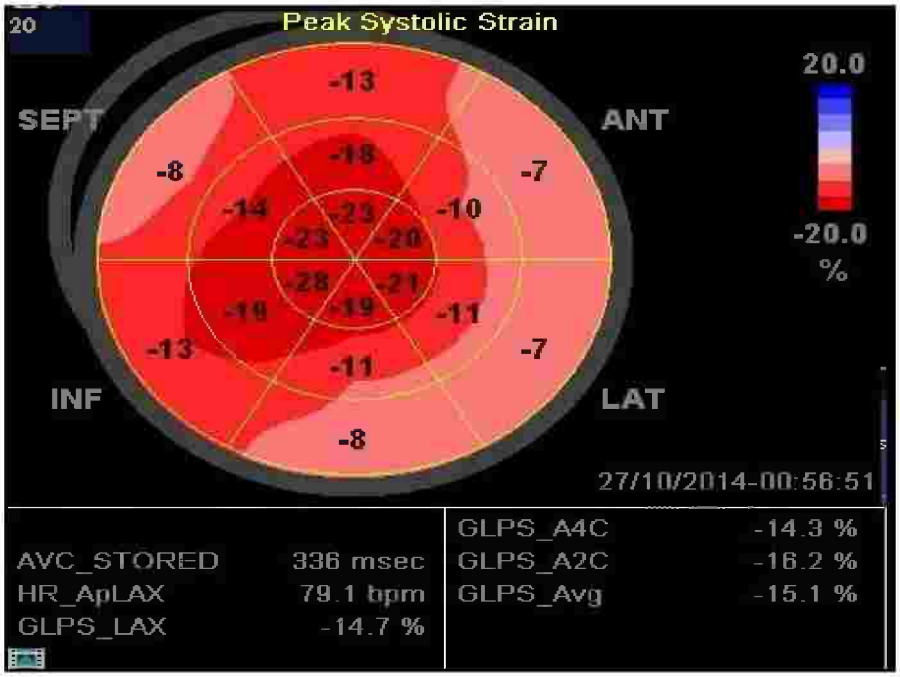


A

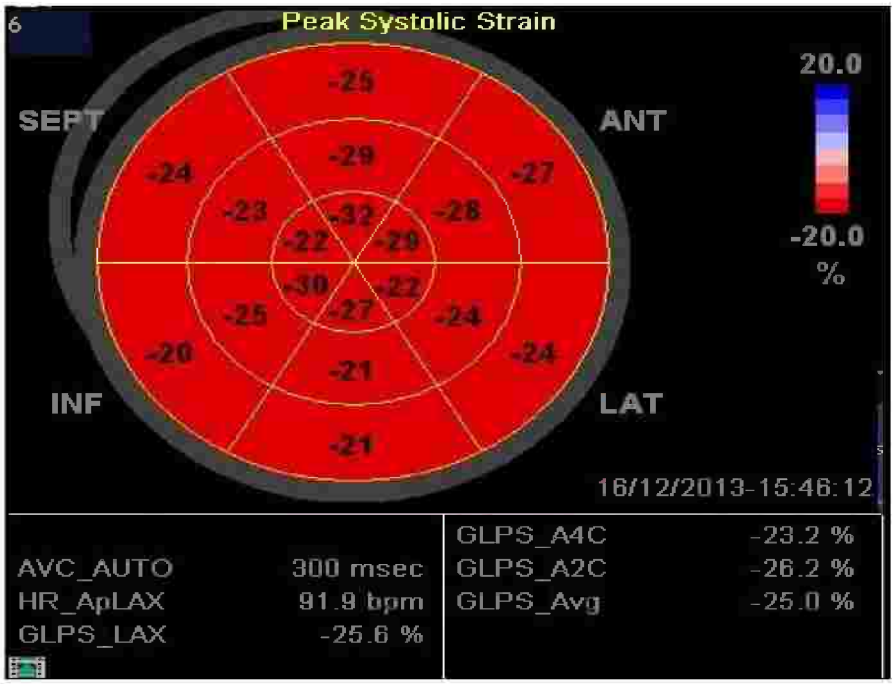


B

Figure (23): Comparison of the strain curves and bull's eye derived from all three apical views in a quad format between case A from the high risk group and case B from the normal group this allows the user to correlate the strain curves with the bull's eye.



A



B

Figure (24): Comparison of 2D STE measurement of segmental and global peak systolic longitudinal strain (PSLS) in bull's eye display between case A from the high risk group and case B from the normal group.

Receiver Operating Characteristic Analysis and the Diagnosis of High-Risk Coronary Artery Disease

The receiver operating characteristic (ROC) curves of the global and segmental peak systolic longitudinal strain values were designed and are presented in Figures (25-28); results were significant for all values. The Areas under the Curve (AUCs) calculated from the ROC curves were 0.961 ($p<0.001$) for global PSLS, 0.961 ($p<0.001$) for mid PSLS, 0.899 ($p<0.001$) for basal PSLS, 0.806 ($p<0.001$) for apical PSLS, 0.946 ($p<0.001$) for mid and basal PSLS, respectively.

Operational cutoff values with corresponding predictive characteristics are presented in Table (14). According to ROC curve analysis, for the detection of high-risk CAD, the optimal cutoff value for the detection of high-risk CAD for global PSLS was -17.9 (sensitivity 95% and specificity 95%), for basal PSLS was -15.83 (sensitivity 90% and specificity 80%), for mid PSLS was -17.17 (sensitivity 95% and specificity 90%), , for apical PSLS was -21 (sensitivity 65% and specificity 62.5%), and for basal and mid PSLS was -16.5 (sensitivity 95% and specificity 87.5%), respectively.

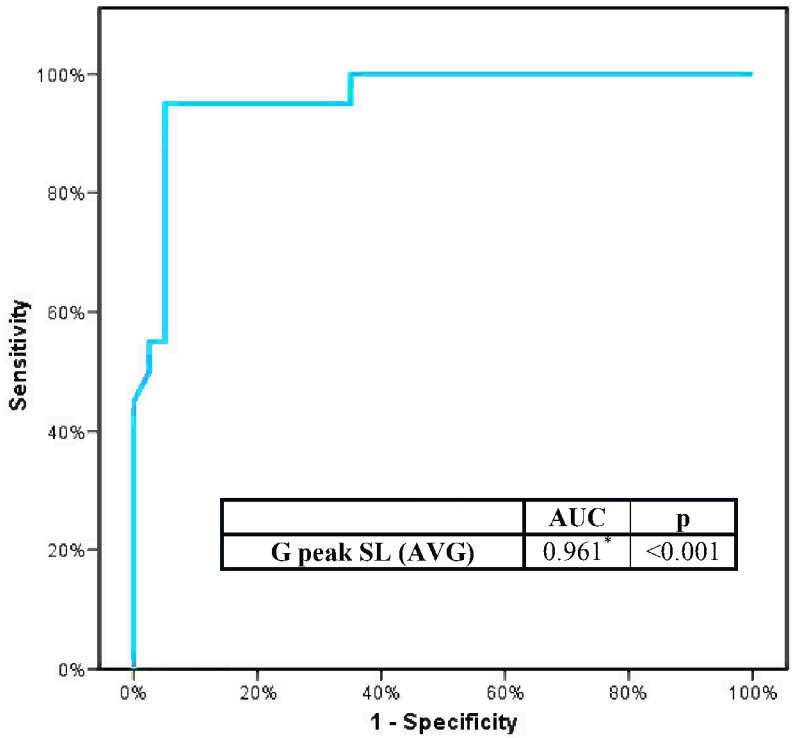


Figure (25): ROC curve for G peak SL (AVG) to diagnose high risk patients

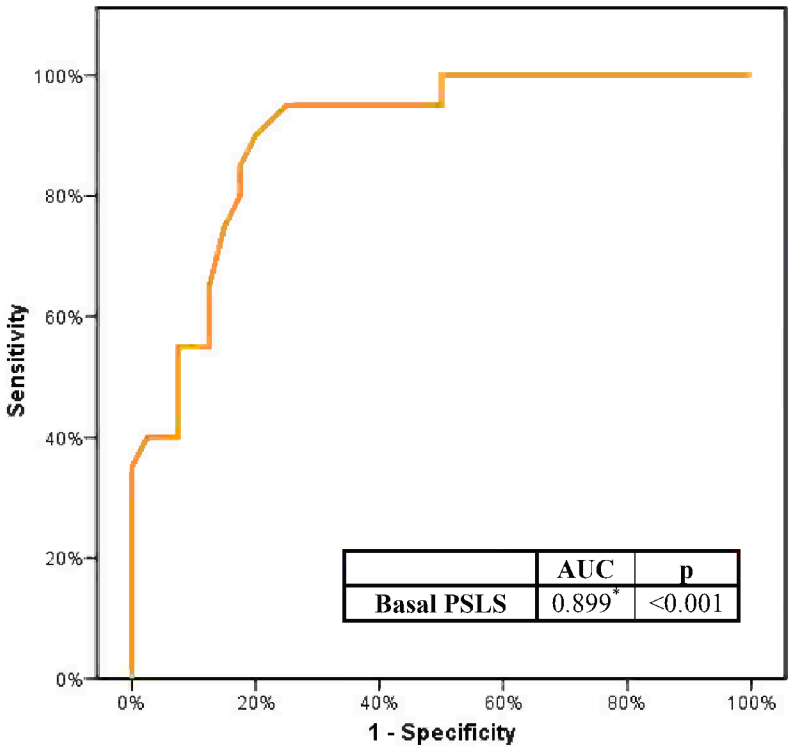


Figure (26): ROC curve for Basal PSLS to diagnose high risk patients.

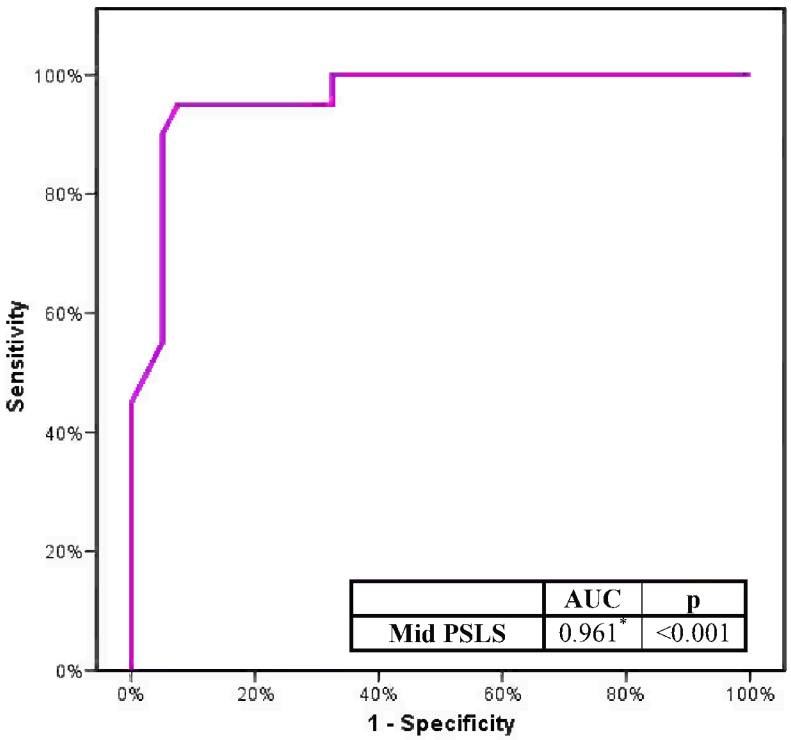


Figure (27): ROC curve for Mid PSLS to diagnose high risk patients.

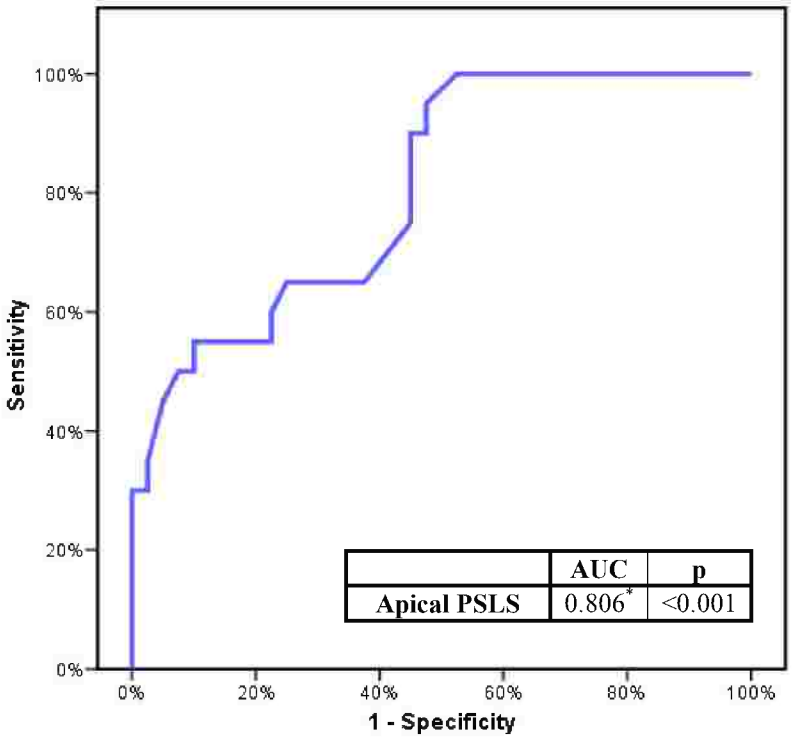


Figure (28): ROC curve for Apical PSLS to diagnose high risk patients.

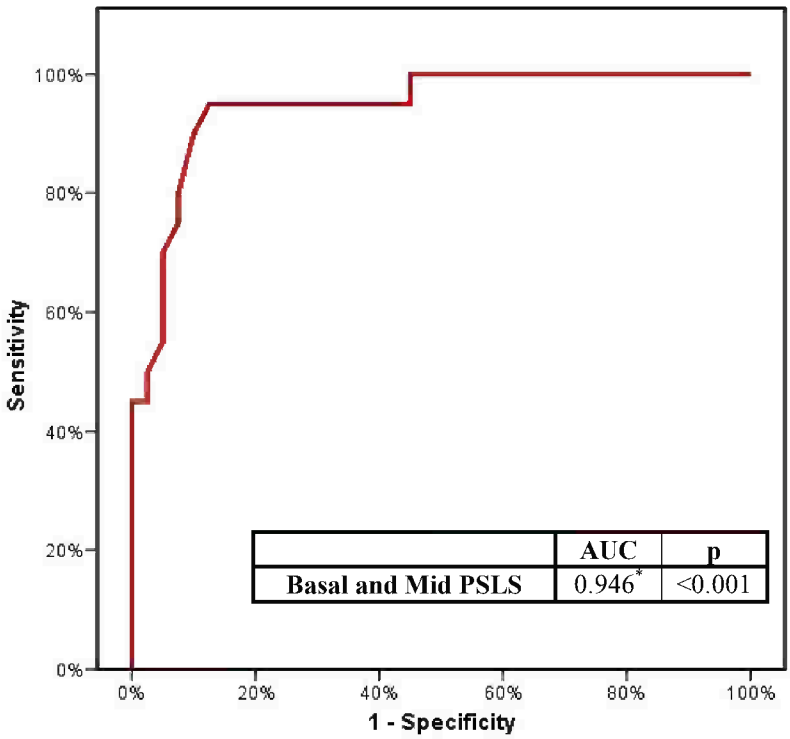


Figure (29): ROC curve for Basal and Mid PSLS to diagnose high risk patients

Table (14): Predictive characteristics of clinical and echocardiographic variables for the detection of high risk coronary artery disease.

	Cut-off value	Sensitivity	Specificity	AUC	p value
LV end diastolic volume	-	-	-	0.604	0.193
LV end systolic volume	-	-	-	0.594	0.240
LV ejection fraction	-	-	-	0.484	0.845
G peak SL (AVG)	-17.9	95.0	95.0	0.961*	<0.001
Basal PSLS	-15.83	90.0	80.0	0.899*	<0.001
Mid PSLS	-17.17	95.0	90.0	0.961*	<0.001
Apical PSLS	-21	65.0	62.5	0.806*	<0.001
Basal and Mid PSLS	-16.5	95.0	87.50	0.946*	<0.001