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## REVIEW

## Echocardiographic predictors of atrial fibrillation after mitral valve replacement



Al-Shimaa Mohamed Sabry\*, Heba Abd El-Kader Mansour, Tarek Helmy Abo El-Azm, Shimaa Ahmed Mostafa, Basant Samy Zahid

Cardiology Department, Faculty of Medicine, Benha University, Egypt

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## ABSTRACT

**Objectives:** Detection of the echocardiographic predictors of post-operative atrial fibrillation in patients with rheumatic mitral valve disease undergoing mitral valve replacement.

**Methods:** The study included 50 patients with rheumatic mitral valve disease undergoing mitral valve replacement. Preoperative assessment included standard two-dimensional echocardiography to assess LA diameter, volume, and emptying fraction, LV volume and ejection fraction. TDI derived velocity, strain of the left atrium and speckle tracking to assess left ventricular function then postoperative follow up for 1 month for occurrence of atrial fibrillation.

**Results:** The incidence of postoperative AF was 44%; these patients were significantly older ( $P = 0.001$ ) and show higher prevalence of DM ( $P = 0.001$ ) and HTN ( $P = 0.001$ ). Also, LA diameters (antero-posterior, transverse and longitudinal) and LA volumes (maximal and minimal) were increased ( $P < 0.001$ ), but no difference in LA emptying fraction ( $P > 0.05$ ). Systolic LA strain and left ventricular global longitudinal strain were significantly reduced in those patients ( $P$  value  $< 0.001$ ). Echocardiographic predictors of AF were LA systolic strain ( $P$  value  $< 0.001$ ) and LV global longitudinal strain ( $P$  value = 0.003). Cutoff value for systolic LA strain  $\leq 23$  had sensitivity 90.91% and specificity 93.33% in predicting POAF. While, left ventricular global longitudinal strain  $\leq -14.9\%$  had sensitivity 63.6% and specificity 100.0% in predicting AF.

**Conclusion:** LA systolic strain and LV global longitudinal strain were significant predictors of POAF. Echocardiographic parameters can identify patients at greater risk of developing POAF who can benefit from preventive measure and guide the selection of prosthesis.

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\* Corresponding author.

E-mail address: [dr.shimaasabry@yahoo.com](mailto:dr.shimaasabry@yahoo.com) (A.-S.M Sabry).<http://dx.doi.org/10.1016/j.ehj.2017.07.002>

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## 1. Introduction

Postoperative atrial fibrillation (POAF) is the most common arrhythmia after cardiac surgery with an incidence ranging between 33% and 49%.<sup>1</sup> Post-operative atrial fibrillation (AF) is considered as benign and without serious consequences, but post-operative AF is associated with increased early and late mortality after mitral valve replacement as there are more frequent embolic events, respiratory and heart failure, longer stay in ICU and hospital, as well as increase in therapy costs.<sup>2</sup>

POAF is mostly detected on the second postoperative day and is frequently self-limiting. Up to 80% of AF patients convert to sinus rhythm (SR) within 24 h, and 98% of patients have converted to SR after six weeks.<sup>3</sup>

Impaired left ventricular (LV) mechanical function assessed by echocardiography (LV ejection fraction) was associated with POAF.<sup>4</sup> However, the role of subclinical LV mechanical function assessed by two-dimensional (2D) speckle-tracking imaging is less clear. Lower values of LV global longitudinal strain, measured by speckle-tracking echocardiography (STE), were associated with POAF in patients with aortic stenosis.<sup>5</sup>

As most of studies focused on determinant of POAF after CABG or aortic valve replacement, the importance of detection of the incidence and precise determinants of AF after mitral valve surgery had been emerged.

The aim of the present study was to detect the echocardiographic predictors of post-operative atrial fibrillation in patients with rheumatic mitral valve disease undergoing mitral valve replacement.

## 2. Patients and methods

It was a single center, prospective, clinical trial that was conducted at cardiology department from August 2015 to May 2016. The study included patients with rheumatic mitral valve disease and in sinus rhythm who were eligible for mitral valve replacement in cardiothoracic department. St. Jude bileaflet valve was used for all the patients with the valve size ranging from 23 to 29 according to the diameter of the annulus and the body surface area of the patient.

Consent from the patients and the approval from the ethical committee were obtained.

Exclusion criteria included patients with comorbidities precluding cardiac surgery, permanent AF or history of paroxysmal AF, impaired LV systolic function (EF less than 40%), associated aortic valve disease necessitating concomitant aortic valve replacement, congenital heart diseases, CAD indicated for concomitant CABG, prior cardiac surgery, and patients refusing to participate in this study.

### 2.1. All patients were subjected to the following

- Demographic data (age & gender), comorbidities as hypertension, diabetes mellitus, history of CHF, history of rheumatic fever, receiving long acting penicillin and cardiac medications (Beta-blockers, ACE inhibitors & statins).
- Full clinical examination with particular emphasis on the pulse and blood pressure, as well as auscultation of the back to elicit the presence of any clinically detectable pulmonary venous congestion, detecting systemic congestion and auscultation of the heart for the presence of third heart sound or audible murmurs.
- **Electrocardiography:** Twelve lead resting ECG was done for each patient pre- and post-operative with a Cardio Fax C machine. The ECG was recorded at a paper speed of 25 mm/s

and an amplification of 10 mm /mv. Pre-operative ECG was done as baseline confirming sinus rhythm of the patient and for comparing it with post-operative ECG to detect whether the patient's rhythm became AF or not. Post-operative ECG and telemetry were used to detect any occurrence of AF in the first 30 days post-operatively.

- **Echocardiography:** Two-dimensional echocardiography and Doppler examination were performed with a GE Vivid 7 Ultrasound Machine (Echo Pac; GE Vingmed, Horten, Norway) with a multi frequency transducer equipped with DTI software and conducted to a single-lead ECG. All examinations were performed in the left lateral position.

- **LA dimensions:** LA diameters were measured at the end-ventricular systole when the LA chamber is at its greatest dimension, in the parasternal long-axis view (anteroposterior diameter) and in the apical 4-chamber view (longitudinal and transverse diameters).<sup>6</sup>

- **LA volumes:** minimal LA volume (Vmin), measured just before the closure of the mitral valve in end-diastole; and maximal LA volume (Vmax), measured just before the opening of the mitral valve in end-systole.<sup>6</sup> The difference between maximum and minimum LA volume divided by the maximum LA volume was used to detect atrial emptying fraction.

- **LV volumes and ejection fraction:** global LV function was assessed by measuring LV end-diastolic volume (LVEDV), LV end-systolic volume (LVESV) and LVEF from the apical 2- & 4-chamber views, using modified Simpson's method.<sup>7</sup>

- The severity of mitral stenosis was assessed by

1. **Planimetry at the parasternal short axis view;** Valve area less than 1.0 cm<sup>2</sup> indicates severe mitral stenosis. Valve area from 1.0 to 1.5 cm<sup>2</sup> indicates moderate mitral stenosis. While, valve area more than 1.5 cm<sup>2</sup> indicates mild mitral stenosis.

2. **Mean transvalvular gradient across the mitral valve:**

- o Mean transvalvular gradient more than 10 mmHg indicates severe MS
- o Mean transvalvular gradient from 5 to 10 mmHg indicates moderate MS
- o Mean transvalvular gradient less than 5 mmHg indicates mild MS<sup>8</sup>

- **The severity of mitral regurge** was assessed by color Doppler jet area. Jet area of more than 8 cm<sup>2</sup> indicates severe mitral regurge, 4–8 cm<sup>2</sup> indicates moderate mitral regurge and less than 4 cm<sup>2</sup> indicates mild mitral regurge.<sup>9</sup>

- **Doppler Tissue Imaging:** pulsed wave Doppler tissue imaging (DTI) was performed in the apical views to acquire mitral annular velocities. Measurements included the systolic (S), early diastolic (E'), and late diastolic (A') velocities.<sup>10</sup> The sample volume was placed on the mitral annulus in the apical four- and two-chamber views.

- **Strain Doppler Method:** real-time 2D color Doppler myocardial imaging data are recorded from the LA, using standard apical views at a high frame rate (>180 fps). The data are stored in digital format and analyzed offline by dedicated software that allows calculating local peak systolic strain.<sup>11</sup>

- **Left ventricular global longitudinal strain:** standard two-dimensional grey scale loops of the left ventricle were acquired in conventional apical four-chamber, two chamber and long axis views. Data were stored digitally and transferred for offline analysis, and special care was taken to ensure frame rates of between 50 and 90 frames per second in all patients. The regions of interest were defined manually by marking the endocardial border, the automatic tracking of endocardial contour was verified carefully and the region of interest was corrected

manually to ensure optimal tracking of the entire myocardial wall. Segmental strain analysis was performed by dividing each left ventricular image into six segments; peak systolic longitudinal strain was calculated by averaging the peak systolic value of the eighteen segments, derived from the three apical views.<sup>12</sup>

- **Coronary angiography** was done pre-operative for patients if indicated. Reduction of the normal diameter by  $\geq 50\%$  was considered to define significant coronary artery stenosis in the left main coronary artery. A cutoff value of 70% was used for the right coronary, left anterior descending and circumflex arteries. Multivessel coronary artery disease was defined as significant stenosis in two or more vessels.<sup>13</sup>
- **STS score:** all patients underwent calculation of the percentage of risk of mortality and percentage of occurrence of morbidity pre-operatively by STS score for mitral valve replacement only.<sup>14</sup> The scoring was done by online calculator using the following data:
  - Age, sex, height (in cm) and weight (in kg).
  - Left ventricular ejection fraction LVEF%, heart failure within 2 weeks of admission, presenting symptoms at admission, presenting symptoms at time of surgery and creatinine level.
  - Presence of COPD, presence diabetes and the type of treatment if diabetic and hypertension.
  - Mitral regurge or stenosis and if regurge degree of regurge, presence of associated aortic or tricuspid valve disease and their degree if present.
  - Coronary anatomy/disease, presence of cerebrovascular disease, presence of peripheral arterial disease.
  - History of MI and history of cardiac arrhythmia.
  - Immunocompromise (which indicate whether immunocompromise is present due to immunosuppressive therapy within 30 days preceding the operative procedure).
  - Endocarditis.
  - Resuscitation, if done or not and if needed was it done within one hour from the start of the operation, or more than one hour but less than twenty four hours
  - Cardiogenic shock, if occurred or not and if occurred was it in the procedure or after but within 24 h.
  - IABP, if was needed or not
  - Inotropic support if was used or not.
  - Previous cardiac intervention was occurred or not and if occurred was it PCI or not.
  - Incidence, was it the first cardiovascular surgery, the first re-op cardiovascular surgery, the second cardiovascular surgery or the third cardiovascular surgery.
  - Was the surgery elective, urgent, emergent or emergent salvage.
  - History of CABG.
  - History of previous valve replacement.
- **Intra-operative and post-operative factor:** duration of ventilation, cardiopulmonary bypass time, cross-clamping, ICU admission and post-operative inotropic support if needed.
- **Statistical analysis:** the collected data were summarized in terms of mean  $\pm$  standard deviation (SD) and range for quantitative data and frequency and percentage for qualitative data. Comparisons between the different study groups were carried out using the Chi-square test ( $\chi^2$ ) and Fisher Exact test (FET) to compare proportions as appropriate. The Student *t*-test (*t*) was used to detect difference in the mean between two parametric data, while the Mann-Whitney test (*z*) was used to compare two non-parametric data. Receiver Operating Characteristics (ROC) analysis was carried out to evaluate the diagnostic performance of LV GLS and LA strain for post-operative AF. The best cutoff point and the corresponding sensitivity and specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV) and Area under the Curve (AUC) were estimated. Stepwise logistic regression analyses for post-

operative AF conditioned on pre-operative clinical data, pre-operative data and echocardiographic parameters were carried out and the results were presented as OR and 95% CI. Comparisons between the models based on the corresponding log likelihood (the smaller the better) and AUC (the greater the better). After the calculation of each of the test statistics, the corresponding distribution tables were consulted to get the “*P*” (probability value). Statistical significance was accepted at *P* value  $<0.05$  (S). A *P* value  $<0.001$  was considered highly significant (HS) while a *P* value  $>0.05$  was considered non-significant. The statistical analysis was conducted using STATA/SE version 11.2 for Windows (STATA corporation, College Station, Texas).

### 3. Results

During the study period, 71 patients with rheumatic mitral valve diseases underwent mitral valve replacement, 21 patients were excluded as 9 patients had associated aortic valve diseases necessitating aortic valve replacement, 7 patients had CAD necessitating CABG and 5 patients died postoperatively, so that only 50 patients fulfilled the eligibility criteria.

Of the 50 patients included in the present study, 32 patients were females (64%) and 18 patients were males (36%). Their age ranged from 30 to 61 years with mean age ( $49.66 \pm 7.37$ ) years. Of the study population, 17 patients were diabetic (34%), 16 patients were hypertensive (32%) and 15 patients were dyslipidemic (30%) and their mean body mass index (BMI) was  $28.71 \pm 1.01$  kg/m<sup>2</sup>. Regarding pre-operative drugs, 29 patients were on beta blockers (58%), 11 patients were on ACE inhibitors (22%) and 6 patients were on statins (12%). 34 patients (68%) had mitral stenosis (27 patients “79.41%” of them had isolated mitral stenosis and 7 patients “20.58%” had combined stenosis and regurge with predominant stenosis). While, 16 patients (32%) had mitral regurge (12 patients “75%” of them had isolated regurge and 4 patients “25%” had combined regurge and stenosis with predominant regurge) (Table 1).

During the post-operative period (during first 30 days post-operative), 22 patients (44%) developed AF (group 1) and 28 (56%) patients remained in sinus rhythm (group 2). Patients who developed AF included 9 patients (40.91%) with paroxysmal AF and 6 patients (27.27%) with persistent AF.

Patients with group 1 were significantly older than group 2 ( $53.32 \pm 6.9$  vs.  $46.78 \pm 6.49$  years,  $P = 0.001$ ). DM (59.09% vs. 14.29%,  $P$  value 0.001) and HTN (50% vs. 17.86%,  $P$  value = 0.001) and statins usage (27.27% vs. 0%,  $P$  value = 0.005) were more prevalent in patients who developed AF. While Beta-blocker usage (31.82% vs. 78.57%,  $P$  value = 0.001) was lower in group 1 as shown in Table 1.

Patients who developed AF had significantly greater body mass index ( $29.54 \pm 0.71$  vs.  $28.07 \pm 0.68$ ;  $P$  value  $<0.001$ ), diastolic blood pressure ( $72.5 \pm 7.2$  vs.  $68.17 \pm 5.49$ ;  $P$  value = 0.02) and heart rate ( $78.64 \pm 7.27$  vs.  $73.5 \pm 4.94$ ;  $P$  value = 0.004), respectively. While there was no significant statistical difference between the 2 groups as regards the systolic blood pressure ( $113.41 \pm 11.06$  vs.  $111.17 \pm 9.07$ ;  $P$  value = 0.43). Thirty-four patients had mitral stenosis, 15 of them developed POAF (68.18%) and 16 patients had mitral regurge, 7 of them developed POAF (31.82%). 15 patients of those who had MS developed POAF representing 68.18% of group I and 7 patients of those who had MR developed POAF representing 31.82% of group I ( $P$  value = 0.91) Table 1.

#### 3.1. Conventional echocardiographic parameters

LA diameters (antero-posterior, transverse and longitudinal) were significantly increased in group 1 ( $4.84 \pm 0.17$  vs.  $4.51 \pm 0.09$  cm,  $4.61 \pm 0.13$  vs.  $4.35 \pm 0.11$  cm and  $6.13 \pm 0.25$  vs.

**Table 1**  
Baseline demographic & clinical data of the studied groups.

Variable	Overall patients	Group 1 POAF (n = 22)	Group 2 No POAF (n = 28)	P value
Age (Mean ± SD)	49.66 ± 7.37	53.32 ± 6.9	46.78 ± 6.49	0.001
Gender:				
Male	18 (36%)	7 (31.82%)	11 (43.33%)	0.4
Female	32 (64%)	15 (68.18%)	17 (56.67%)	
Comorbidities:				
Diabetes mellitus	17 (34%)	13 (59.09%)	4 (14.29%)	0.001
Hypertension	16 (32%)	11 (50%)	5 (17.86%)	0.02
Dyslipidemia	15 (30%)	10 (45.45%)	5 (17.86%)	0.03
Patients' clinical data:				
Heart rate (bpm)	75.67 ± 6.4	78.64 ± 7.27	73.5 ± 4.94	0.004
Systolic blood Pressure (mmHg)	112.11 ± 9.	113.41 ± 11.06	111.17 ± 9.07	0.43
Diastolic blood Pressure (mmHg)	92	72.5 ± 7.2	68.17 ± 5.49	0.02
BMI (kg/m <sup>2</sup> )	28.71 ± 1.01	29.54 ± 0.71	28.07 ± 0.68	<0.001
Medications:				
Beta-blockers	29 (58%)	7 (31.82%)	22 (78.57%)	0.001
ACE inhibitors	11 (22%)	6 (27.27%)	5 (17.86%)	0.5
Statins	6 (12%)	6 (27.27%)	0 (0%)	0.005
Type of mitral valve lesions:				
MS	34 (68%)	15 (68.18%)	19 (67.86%)	0.91
MR	16 (32%)	7 (31.82%)	9 (32.14%)	

**Table 2**  
Echocardiographic parameters of the studied groups.

Variable	POAF (n = 22)	No POAF (n = 28)	P value
Echocardiography:			
LA antero-posterior diameter	4.84 ± 0.17 cm	4.51 ± 0.09 cm	<0.001
LA longitudinal diameter	6.13 ± 0.25 cm	5.39 ± 0.18 cm	<0.001
LA transverse diameter	4.61 ± 0.13 cm	4.35 ± 0.11 cm	<0.001
LA maximal volume	103.68 ± 3.66 ml	93.23 ± 3.96 ml	<0.001
LA minimal volume	66.18 ± 7.85 ml	54.9 ± 3.25 ml	<0.001
LA emptying fraction	37.04 ± 7.74%	40.47 ± 5.39%	0.08
LVESV	37.77 ± 18.16 ml	25.5 ± 1.04 ml	<0.001
LVEDV	78.91 ± 22.94 ml	68.1 ± 2.54 ml	0.06
LV EF	53.77 ± 7.71%	62.37 ± 2.2%	<0.001
PASP	49.82 ± 3.42 mmHg	47.9 ± 1.9 mmHg	0.01
TDI:			
S	0.08 ± 0.01 m/s	0.08 ± 0.01 m/s	0.08
E'	0.11 ± 0.03 m/s	0.14 ± 0.02 m/s	<0.001
A'	0.76 ± 0.07 m/s	0.82 ± 0.08	0.01
E/E' ratio	9.84 ± 2.15	6.19 ± 1.16	<0.001
Systolic LA strain	19.53 ± 0.51%	23.45 ± 0.27%	<0.001
LV GLS	-14.27 ± 1.61%	-20.25 ± 1.02%	<0.001

5.39 ± 0.18 cm, respectively; *P* value <0.001). Also, the LA volumes (maximal and minimal) were significantly increased in those with POAF (103.68 ± 3.66 vs. 93.23 ± 3.96 ml and 66.18 ± 7.85 vs. 54.9 ± 3.25 ml; respectively, *P* < 0.001). There was no significant statistical difference between the 2 groups as regards left atrial emptying fraction (37.04 ± 7.74 vs. 40.47 ± 5.39% respectively; *P* value = 0.08).

Group 1 had significantly greater left ventricular end-systolic volume (LVESV) (37.77 ± 18.16 vs. 25.5 ± 1.04 ml; *P* value <0.001) and significantly reduced left ventricular ejection fraction (LVEF) (53.77 ± 7.71 vs. 62.37 ± 2.2%; *P* value <0.001). While, there was no significant statistical difference as regards left ventricular end diastolic volume (LVEDV) was observed between the 2 groups (78.91 ± 22.94 vs. 68.1 ± 2.54 ml; *P* value = 0.06). Pulmonary artery systolic pressure (PASP) was significantly greater in those who developed AF (49.82 ± 3.42 vs. 47.9 ± 1.9 mmHg; *P* value = 0.01) (Table 2).

### 3.2. Doppler tissue imaging

In group 1, early (E') and late (A') diastolic mitral annular velocity (e') were significantly decreased (0.11 ± 0.03 vs. 0.14 ± 0.02 m/s; *P* value <0.001 and 0.76 ± 0.07 vs. 0.82 ± 0.08 m/s; *P* value = 0.01, respectively). While, E/E' ratio was significantly greater (9.84 ± 2.15 vs. 6.19 ± 1.16; *P* value = 0.001). There was no significant statistical difference between the 2 groups as regards (S') wave velocity (0.08 ± 0.01 vs. 0.08 ± 0.01 m/s; *P* value = 0.08).

Systolic LA strain was significantly reduced in group 1 patients (19.53 ± 0.51 vs. 23.45 ± 0.27%, *P* < 0.001) (Table 2). Left ventricular global longitudinal strain (LVGLS %) was significantly reduced in POAF patients (-14.27 ± 1.61 vs. -20.25 ± 1.02%; *P* value <0.001).

Thirty-one patients (62%) underwent diagnostic coronary angiography. Of them 25 patients (80.6%) had normal coronary angiographic results, one patient (3.2%) had non-significant lesion in RCA, 2 patients (6.5%) had non-significant lesion in LCX and 3 patients (9.7%) had non-significant lesion in LAD. There was no significant difference between the 2 groups as regards the results of diagnostic coronary angiography.

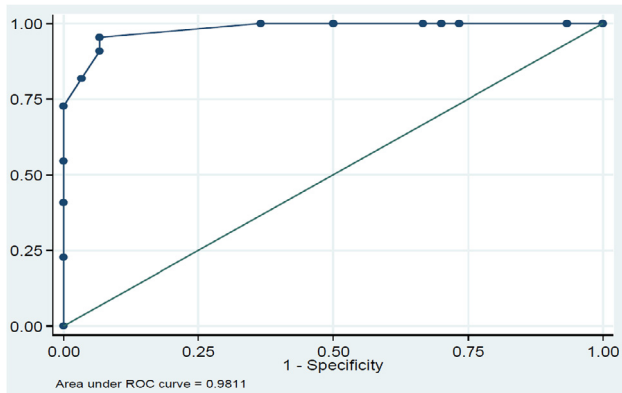
The data obtained from (STS) score showed significantly increased risk of mortality and morbidity in group 1 (2.08 ± 0.76 vs. 0.89 ± 0.16, 26.94 ± 6.38 vs. 12.32 ± 3.2; respectively, *P* value <0.001). Cardio-pulmonary bypass time and ischemic time were significantly greater in POAF patients (137.68 ± 10.91 vs. 118.71 ± 4.60 min. and 79.27 ± 17.2 vs. 72.86 ± 2.49 min. respectively; *P* value <0.001). Also, ventilator time and ICU duration were significantly longer in POAF (13.66 ± 6.58 vs. 6.59 ± 0.44hrs. and

**Table 3**  
Logistic regression analysis including pre-operative clinical data.

Variable	OR	95% CI	P
Sex (female vs. male)	10.62	0.91–123.38	0.059
Beta blockers use	0.005	0.00–0.22	0.006
Diastolic BP	1.50	1.12–2.02	0.006
Heart rate	1.43	1.09–1.89	0.011
Log likelihood	-15.09		
AUC	0.9367		
Hosmer-Lemeshow statistic	0.24		
P	0.97		

**Table 4**  
Logistic regression analysis including echocardiographic parameters.

Variable	OR	95% CI	P
LA systolic strain	0.15	0.05–0.43	<0.001
LV GLS	0.45	0.22–0.93	0.03
Log likelihood	–6.81		
AUC	0.9919		
Hosmer-Lemeshow statistic	2.39		
P	0.97		

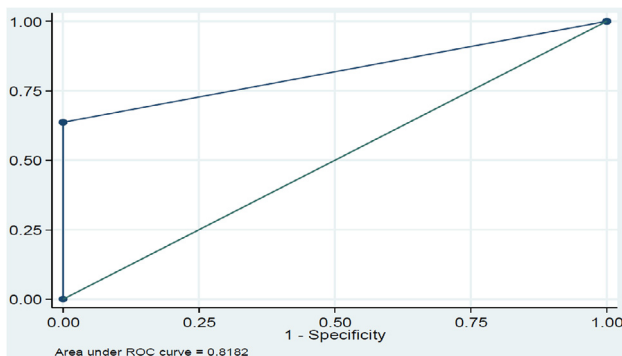


**Fig. 1.** Roc curve of LA systolic strain.

36.95 ± 15.07 vs. 23.1 ± 0.99 hrs. respectively; *P* value <0.001). Group I had more patients who underwent tricuspid valve repair 14 patients (63.64%) vs. 9 patients (30.0%); *p* value = 0.02.

Multi-variate logistic regression analysis including preoperative clinical data (age, gender, DM, HTN, dyslipidemia,  $\beta$  blockers, statins, ACE inhibitors, BMI, heart rate, systolic and diastolic blood pressure) was done. The preoperative clinical data associated with POAF were gender (*P* value = 0.059),  $\beta$  blockers (*P* value = 0.006), heart rate (*P* value = 0.006) and diastolic blood pressure (0.006), the area under the curve (AUC) was (0.9659) (Table 3). While the echocardiographic parameters associated with POAF were LA systolic strain (*P* value <0.001) and LVGLS % (*P* value = 0.003), the area under the curve (AUC) was (0.9919) (Table 4).

The receiver-operator characteristic (ROC) curve was used to test diagnostic value of left atrial systolic strain (LA strain %) and left ventricular global longitudinal strain (LVGLS %) in predicting POAF in patients with MVD undergoing mitral valve replacement. The value of systolic LA strain  $\leq 23$  was shown to have the best diagnostic accuracy (sensitivity = 90.91%; specificity = 93.33%) in predicting the presence of POAF, with an AUC of 0.9811 (95%CI “0.952–1.01”) (Fig. 1). The value of left ventricular global longitudinal



**Fig. 2.** Roc curve of left ventricular global longitudinal strain.

strain (LVGLS)  $\leq -14.9$  was shown to have the best diagnostic accuracy (sensitivity = 63.6%; specificity = 100.0%) in predicting the presence of POAF, with an AUC of 0.8182 (95%CI “0.71–0.92”) (Fig. 2). Figs. 3 and 4 show left atrial systolic strain and left ventricular global longitudinal strain of 2 cases, one of them developed atrial fibrillation and the other remained in sinus rhythm.

#### 4. Discussion

The aim of the present study was to determine the predictors of POAF in patients with rheumatic MVD scheduled for mitral valve replacement for either mitral stenosis or regurg as preoperative assessment and preventive management for POAF would be beneficial for improving prognosis in these patients.

In the current study, atrial fibrillation (AF) was a common complication after mitral valve replacement, occurring in 44% of the patients (22/50 patients). Patients who developed POAF were older in age, a finding consistent with previous reports by Osranek et al.,<sup>15</sup>

In the current study, more patients of those who developed POAF had history of DM, HTN and dyslipidemia. However,  $\beta$ -blockers usage was associated with less incidence of AF. These findings are in agreement with Bařaran et al.,<sup>16</sup> who reported POAF group weren't on beta-blockers (*P* value <0.001)

LA size is a commonly used parameter for evaluation of LA structural changes. Studies have shown that LA size (both LA diameter and LA volume) was predictive of AF development in general population.<sup>17</sup> LA volume has been shown to provide a more precise assessment of LA size than LA diameter because of the asymmetric nature and enlargement of the chamber.<sup>18</sup>

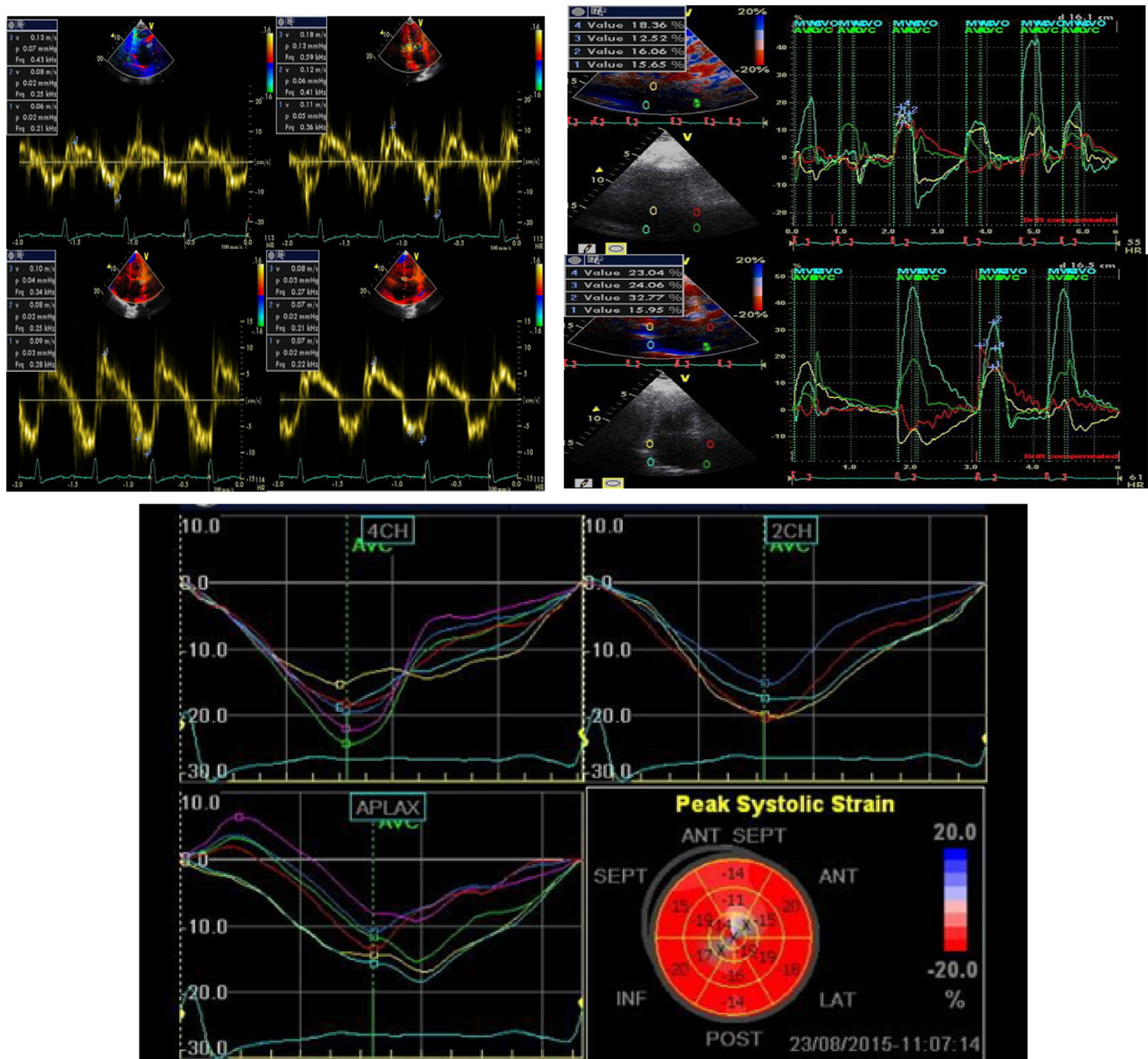
In the current study, patients of POAF group had larger left atrial antero-posterior, transverse and longitudinal diameters (*P* value <0.001), a finding consistent with Kernis et al.,<sup>19</sup> also Cheng et al.<sup>20</sup> who used LA diameter as an independent predictor of POAF after minimally invasive mitral valve surgery reported that patients who developed POAF had larger LA diameter (*P* value <0.001).

In addition, the present study showed that the LA volumes (maximal and minimal) were significantly increased in patients who developed POAF (*P* value <0.001). This is consistent with Haffajee et al.,<sup>17</sup> who reported that indexed maximal (*P* value = 0.023) and minimal (*P* value <0.001) LA volumes were larger in the POAF group.

In the current study, there was no significant statistical difference between the 2 groups as regards left atrial emptying fraction (LAEF %). This is in contrast to Haffajee et al.,<sup>17</sup> who reported that LAEF% was significantly reduced in POAF group this could be explained by the presence of patients with CAD in addition to those with valvular disease in their study.

Systolic LA strain was significantly reduced in patients of POAF group (*P* value <0.001). This is consistent with Candan et al.,<sup>21</sup> who reported that LA strain was reduced in POAF group. In addition, Gabriella et al.,<sup>22</sup> who studied patients undergoing CABG demonstrated that STE (speckle tracking echocardiography)-based LA strain and strain rate were lower in patients who developed POAF.

In the present study, speckle tracking echocardiography revealed that the left ventricular global longitudinal strain (LVGLS %) was significantly reduced in POAF group (*P* value <0.001). This is in contrast to Bařaran et al.,<sup>16</sup> who studied the predictive role of left atrial and ventricular mechanical function in postoperative atrial fibrillation. They reported that the left ventricular global longitudinal strain value was not different between the 2 groups (*P* value >0.005). This could be explained by the different group of patients as they studied patients with CAD scheduled for CABG.



**Fig. 3.** A case developed AF 3 days postoperative. (A) TDI velocities showing that S wave = 0.08 m/s, E' wave = 0.08 m/s, A' wave = 0.10 m/s. (B) (TDI) LA strain = 19.8%. (C) LVGLS = -14.1%.

In the current study, data obtained from (STS) score showed significantly increased risk of mortality & morbidity in POAF group ( $P$  value <0.001).

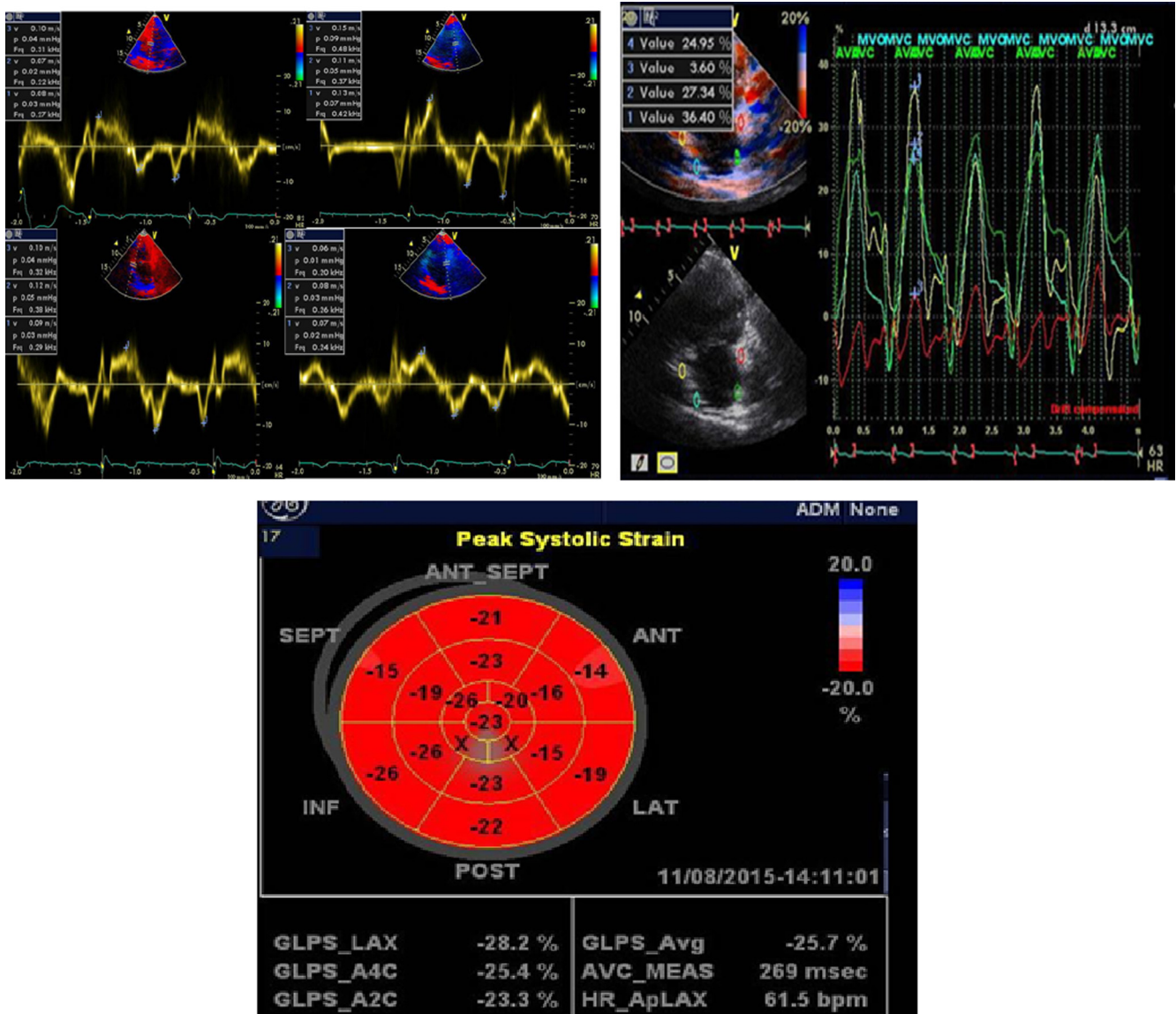
POAF group had more patients underwent tricuspid valve repair ( $P$  value = 0.02). Cardio-pulmonary bypass and cross-clamping times were significantly greater in POAF group ( $P$  value <0.001). This is in contrast to Candan et al.,<sup>21</sup> who reported that there was no significant difference between the 2 groups regarding tricuspid valve repair. They evaluated patients with MR undergoing mitral valve replacement and most of their patients had degenerative MR. Also, Takahashi et al.,<sup>23</sup> reported that there was no significant difference between the 2 groups regarding bypass time and cross-clamping time.

In the present study, multivariate logistic regression included the preoperative clinical data (age, gender, DM, HTN, dyslipidemia,  $\beta$ -blockers use, statins, ACE inhibitor, BMI, heart rate, systolic and diastolic blood pressures). The preoperative clinical data associated

with POAF were gender ( $P$  value = 0.059),  $\beta$ -blockers ( $P$  value = 0.006), heart rate ( $P$  value = 0.006) and diastolic blood pressure (0.006). The area under the curve (AUC) was (0.9659).

While the echocardiographic parameters which were associated POAF were LA strain % ( $P$  value <0.001) and LVGLS% ( $P$  value = 0.003), the area under the curve (AUC) was (0.9919). This is in agreement with Candan et al.,<sup>21</sup> who reported that POAF is associated with reduced LA strain% (odds ratio 0.719, 95% confidence interval 0.545–0.948;  $P$  = 0.019). Levy et al.,<sup>13</sup> reported that LVGLS% less than -15% was significantly associated with a higher risk of POAF (odds ratio 7.74, 95% confidence interval 1.15–52.03;  $P$  = 0.035).

The receiver-operator characteristic (ROC) curve was used to test the diagnostic value of left atrial systolic strain (LA strain %) and left ventricular global longitudinal strain (LVGLS%) in predicting POAF in patients with rheumatic MVD undergoing mitral valve replacement. LA strain cutoff value of  $\leq 23$  was shown to have very good diagnostic



**Fig. 4.** A case did not develop AF. A: TDI velocities showing that S wave = 0.09 m/s, E' wave = 0.09 m/s, A' wave = 0.10 m/s. B: (TDI) LA strain = 23.2%. (C) LVGLS = -25.7%.

accuracy (sensitivity = 90.91%; specificity = 93.33%) in predicting the presence of POAF, with an AUC of 0.9811. The left ventricular global longitudinal strain (LVGLS%) cutoff value of  $\leq -14.9$  has the best diagnostic accuracy (sensitivity = 63.6%; specificity = 100.0%) in predicting the presence of POAF, with an AUC of 0.8182. This is in agreement with Levy et al.,<sup>13</sup> who reported that ROC curve analysis identified a GLS% value of  $-15\%$  as the best cutoff for the prediction of POAF (82% sensitivity, 53% specificity, AUC 0.72).

## 5. Conclusion

LA systolic strain and LV global longitudinal strain were significant predictors of POAF. Echocardiographic parameters can identify patients at greater risk of developing POAF who can benefit from preventive measure and guide the selection of prosthesis.

## 6. Limitation

Small number of patients were included as only patients with mitral pathologies other than rheumatic lesions were excluded and short duration of follow up.

AF was considered present only when objectively documented but may be transient, and all episodes may not be detected. However, it is currently impossible to constantly monitor for "silent" AF occurrences. Hence, it is essential to define the incidence and consequences of detectable AF, the only form of this arrhythmia that presently may lead to therapeutic intervention.

## Conflict of interest

The authors declared that there is no conflict of interest.

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