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ORIGINAL STUDY

# The value of right ventricular systolic function assessment by two dimensional speckle tracking echocardiography in severe mitral stenosis

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**Abstract**

*Background*: **Many patients with long-standing mitral stenosis (MS) experience pulmonary hypertension, which can eventually result in right heart failure. Several studies investigated the right ventricular (RV) function changes in MS patients in the perioperative periods but focused on balloon mitral valvotomy. So our study aimed to assess the RV changes in severe MS patients planned for surgical mitral valve replacement (MVR).**

*Methods*: **A case-control study was carried out on severe MS patients planned for surgical MVR being unfit for balloon mitral valvotomy were subjected to conventional MS indices, RV fractional area change, lateral tricuspid annular plane systolic excursion, RV global longitudinal strain (RV-GLS) and RV free were assessed. Sixty cases were compared with 60 controls before surgery, 1 week postsurgery, and after 3 months.**

*Results*: **Baseline RVGLS and free strain were lower in cases in comparison to the control group, there was a drop in mean values of tricuspid annular plane systolic excursion, RV s, fractional area change, RV-GLS, and free wall at 24 h, then after 3 months follow-up there was a significant improvement.**

*Conclusions*: **MS patients had impaired RV systolic function before MVR. There was a sharp deterioration in RV function 1 week postsurgery then RV systolic function recovered to some extent but was still far away from the control group.**

*Keywords:* Right ventricular function, Severe mitral stenosis, Speckle tracking echocardiography

## 1. Introduction

About 60–90% of cases of rheumatic fever result in rheumatic carditis, which is the chronic manifestation of rheumatic heart disease [1]. Many patients with long-standing mitral stenosis (MS) experience pulmonary hypertension (PH), which can eventually result in right heart failure [2]. In MS, the development of clinical symptoms, exercise ability, prognosis, and survival are all significantly influenced by right ventricular (RV) function [3]. Several studies had investigated the RV function changes in MS patients in the perioperative periods but focused on balloon mitral valvotomy (BMV) [4–7] so our study aimed to assess the RV changes in severe MS patients planned for surgical mitral valve replacement (MVR).

## 2. Methods

### 2.1. Population and study design

A case-control study was conducted on severe MS patients planned for surgical MVR being unfit for

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BMV according to ESC guidelines [8] from September 2023 to June 2024 in the Cardiology department of Zagazig University Hospitals and Al-Ahrar Teaching Hospitals. Patients with overt right heart failure, chronic obstructive pulmonary disease, atrial fibrillation, prior heart surgery, aortic valve stenosis, more than mild AR, poor image quality unfit for speckle tracking echocardiography interpretation. Sixty cases, that fulfilled the inclusion criteria, were investigated for RV speckle tracking, and other echocardiographic parameters of RV function before MVR, and also the effect of MVR on these parameters was also assessed 1 week post-surgery and after 3 months. These parameters were also compared with that of 60 healthy controls.

After getting each participant's signed informed consent, demographic data, and symptoms were recorded, and a standard 12-lead electrocardiogram (ECG) was performed to evaluate the cardiac rhythm.

Conventional Echocardiographic evaluation: Assessment using a 1.5–3.6 MHz multifrequency phased array probe and a Horton, Norway, Vivid E95 commercial ultrasound scanner with phased-array transducers interpreted by two experienced echocardiographers independently. The standard evaluation was conducted in compliance with the guidelines provided by the American Society of Echocardiography and the European Association of Echocardiography [9].

Traditional MS indices were assessed, including mitral valve orifice area (MVOA) and mean diastolic gradient (MDG). Mitral orifice planimetry was used to measure MVOA in the parasternal short-axis view. MVOA, MDG, and pulmonary artery systolic pressure (PASP) were used to calculate the severity of MS, with MVOA less than 1.5 $cm^2$ being the value of severe MS. The Bernoulli equation, which is derived from the peak velocities of tricuspid regurge jets, was used to measure PASP, then the right atrial pressure (RAP) value was added based on inferior vena cava (IVC) diameter and inspiratory collapsibility. PH was defined as PASP values more than 35 mmHg [9].

Detailed RV assessment was done based on the American Society of Echocardiography [9]. To evaluate the lateral tricuspid annular planar systolic excursion (TAPSE), we used the m-mode on the annular lateral tricuspid annular. The RV fractional area change (RVFAC) equation was expressed as RVED area−RVES area/RVED area × 100. RV Systolic (S) wave velocity and myocardial performance index were obtained using Tissue Doppler Imaging in the pulse-Doppler mode of the lateral tricuspid annulus velocity.

Assessment of right ventricle using (STE): RV free wall strain and RV global longitudinal strain (RV-GLS) were assessed in compliance with the recommendations provided by the European Association of Echocardiography and the American Society of Echocardiography [9]. Using the right ventricle-focused view, six segments (basal, middle, and apical) of the right ventricle were identified, and six corresponding strain segments were generated for (RV-GLS). The longitudinal strain of the RV-free wall was calculated by averaging the values of its three peak systolic strain segments.

### 2.2. Follow-up

Follow-up was done 1 week postsurgery before discharge from the hospital and after 3 months through follow-up visits at the echocardiography unit where data of MVOA, MDG, PASP, all aforementioned RV conventional, and strain parameters were assessed.

### 2.3. Ethical standard

The current study was approved by the General Organization for Teaching Hospitals and Institutes (GOTHI) with an IRB number coded as HAH00030, date:9/27/2023.

### 2.4. Statistical analysis

The analysis of the data was done with SPSS version 24.0 (IBM Corp, Armonk, NY, USA) version 21. The mean standard deviation was used to display quantitative data. *P* less than 0.05 was defined as statistically significant. Quantitative variables were compared using the Mann–Whitney test (because the data sets were not normally distributed) between the case and control groups and the Wilcoxon signed-rank test between pre and postcomparisons. Qualitative variables were correlated using the $\chi^2$ test.

## 3. Results

The mean age of cases was 40.08 ± 15.38 years while the control was 36.8 ± 12.9 years with no statistically significant difference regarding age, BMI, and sex difference. Baseline RV-GLS and free strain were lower in cases in comparison to the control group *P* 0.009, and 0.001, respectively (Table 1).

There was an improvement in MVOA, MDG, and PASP at 24 h and after 3 months follow-up with (*P* 0.001), while there was a drop in mean values of TAPSE, RV s, FAC, RV GLS, and free wall at 24 h,

*Table 1. Demographic and strain parameters between case and control.*

| | Case (60) | Control (60) | *P* |
|---|---|---|---|
| Age (year) | | | |
| Mean ± SD | 40.08 ± 15.38 | 36.8 ± 12.9 | 0.89 |
| BMI mean ± SD | 30.5 ± 8.8 | 28.6 ± 6.9 | 0.56 |
| Sex, *n* (%) | | | |
| Female | 33 (55) | 35 (58.3) | 0.45 |
| Male | 27 (45) | 25 (41.7) | |
| RV-GLS% | −15.15 ± 5.89 | 20.5 ± 6.8 | 0.009 |
| RV-free strain | −14.29 ± 7.87 | 22.3 ± 8.9 | 0.001 |

BMI, body mass index; RV, right ventricular; RV-GLS, right ventricular global longitudinal strain; SD, standard deviation.

then there was a significant improvement at 3 month follow-up with (*P* 0.001) (Table 2).

There was a lower mean value of RV-GLS and free strain at 24 h and 3 months in comparison to the control (*P* 0.001) (Table 3).

Figs. 1–4: represent case demonstration of MS case before MVR, 1 week after surgery at discharge from the hospital, after 3 months at the follow-up visit in the echocardiography unit, and control demonstration.

## 4. Discussion

There is not a single validated echocardiographic indicator for measuring RV function. The improvement in RV strain was selected by this current study as a marker for RV systolic function despite the literature's recommendation to assess various parameters. This is because RV strain is a global parameter, it involves the free wall's myocardial contractility, and it has a better prognostic power.

The current study compared 60 patients who had moderately severe MS planned for MVR with 60 healthy volunteers matched nearly with age, sex, and BMI, we found that MS cases had a lower mean value of RV-GLS and free strain in comparison to the control group. The cause of the impaired RV function before surgery was attributed to the moderately-sever PH, this was in agreement with previous studies [4,5,10], and that finding comes with the fact that the high left atrial pressure leads to chronic pulmonary venous congestion followed by PH, which lead to rise in RV afterload and then RV remodeling and impairment [11].

Nonetheless, some articles hypothesized that the reason for this reduced myocardial function is the RV's direct rheumatic involvement, which leads to myocyte necrosis, replacement fibrosis, and calcification [12,13].

After undergoing successful MVR we noticed after 1 week from MVR although significant improvement in MV area, MDG, and PASP there was a significant sharp drop in RV systolic parameters RV s, FAC, TAPSE, and even strain parameters GLS and free strain. Parallel to our results, Tamborini *et al.* [14] reported reduced TAPSE reading on postsurgery analysis. Jadhav *et al.* [10] reported a gradual decrease in all RV parameters postvalve replacement.

On the contrary to studies assessing RV function post-BMV, all reported significant improvement in

*Table 2. Comparison between basal assessment, post 24 h and after follow-up 3 months in cases.*

| | Baseline (60) | 24 h (55) | 3 months (55) | *P* |
|---|---|---|---|---|
| MVOA cm | 0.8 ± **0.01** | 1.7 ± **0.8** | 1.8 ± **0.7** | 0.001 |
| MDG mmHg | 11.9 ± **2.9** | 6.8 ± **1.8** | 5.4 ± **1.9** | 0.001 |
| TAPSE mm | 16.25 ± 3.43 | 10.97 ± 2.92 | 15.5 ± 2.19 | 0.04 |
| RV S wave cm∖s | 9.08 ± 3.25 | 7.18 ± 1.71 | 10.37 ± 2.2 | 0.001 |
| RV MPI | 0.56 ± 0.13 | 0.52 ± 0.09 | 0.53 ± 0.09 | 0.87 |
| FAC% | 39.69 ± 8.61 | 24.94 ± 7.93 | 33.98 ± 5.13 | 0.02 |
| RV-GLS% | −15.15 ± 5.89 | −9.76 ± 4.22 | −17.3 ± 9.2 | 0.001 |
| RV-free strain% | −14.29 ± 7.87 | −10.29 ± 5.17 | −16.31 ± 10.72 | 0.001 |
| PASP mmHg | 54.86 ± 11.56 | 45.88 ± 7.64 | 39.63 ± 5.63 | 0.001 |

FAC, fractional area change; MDG, mean diastolic gradient; MPI, myocardial performance index; MVOA, mitral valve orifice area; PASP, pulmonary artery systolic pressure; RV-—GLS, right ventricular global longitudinal strain; TAPSE, tricuspied annular plane systolic excursion.

* *P* value < 0.05 is significant

*Table 3. Comparison of follow-up variables between cases and control.*

| U | Cases (55) | Control (60) | *P* |
|---|---|---|---|
| RV-GLS 24 h post MVR | −9.76 ± 4.22 | 21.5 ± 10.6 | 0.001 |
| RV-Free strain 24 h post MVR | −10.29 ± 5.17 | 23.6 ± 11.8 | 0.001 |
| RV-GLS 3 months post MVR | −16.9 ± 5.2 | 22.70.±12.92 | 0.001 |
| RV-Free strain 3 months post MVR | −15.31 ± 6.72 | 23.18 ± 11.7 | 0.001 |

MVR, mitral valve replacement; RV-GLS, right ventricular global longitudinal strain.

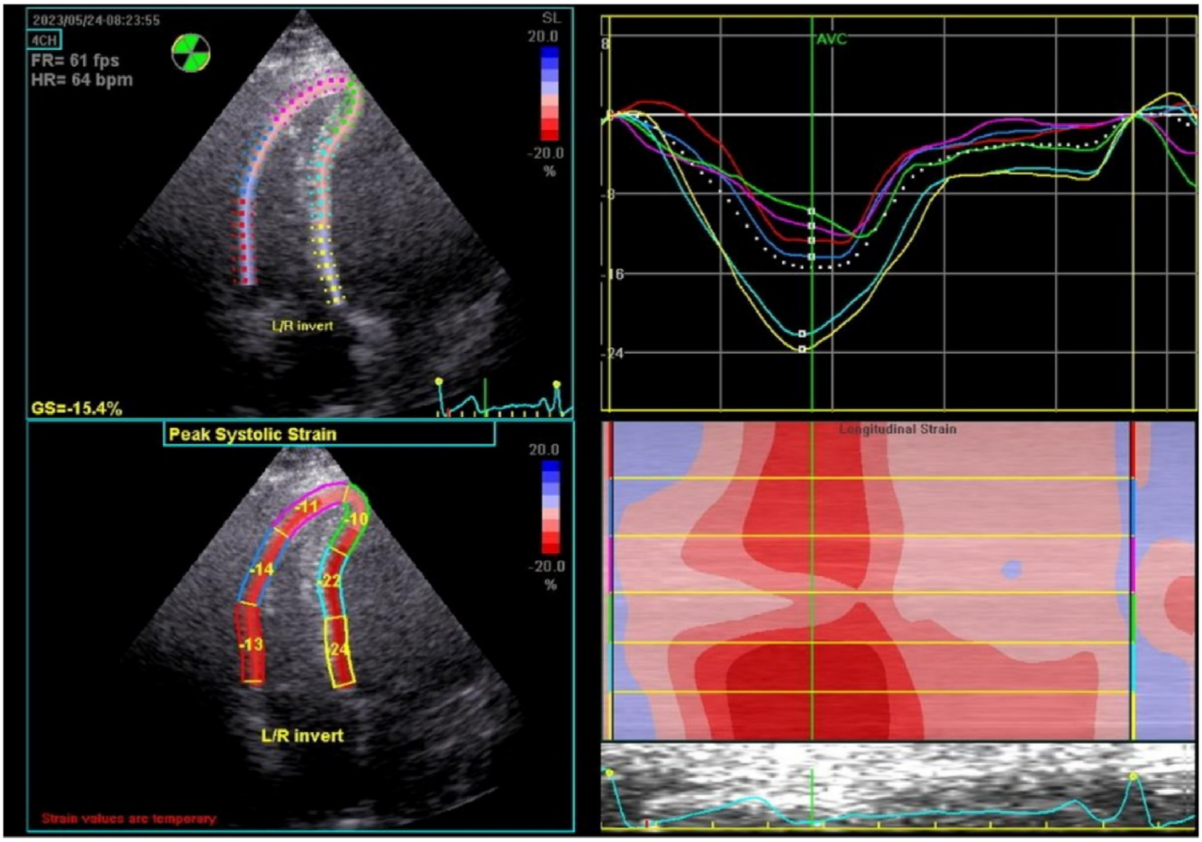


*Fig. 1. Case demonstration baseline assessment showing GS = 15.4% and free strain was calculated manually by averaging the basal, mid, and apical segments 13 + 14 + 11/3 = 12.6%.*

RV measurements in the early postoperative period after 24 h [4,7]. Other studies reported improvement after 48 h postprocedure [6,15]. We could say that the immediate improvement in RV function after BMI was attributed to the fact that BMV preserves the RV geometry and structure unlike surgical valve replacement, Levy *et al.* [16] reported that the cause of sharp deterioration in RV function early post-surgery is attributed to several causes; Atrioventricular synchrony loss or arrhythmias, reperfusion lung injury with secondary PH, postoperative pulmonary micro- or macro-embolism, pre-existing pulmonary vascular disease, protamine-induced PH, and inadequate myocardial protection during surgery are some of the conditions that can cause this.

Varma *et al.* [17] added that acutely increased ventricular dependency, as shown in cardiac tamponade, and a rise in pulmonary vascular resistance or RV afterload are the causes of acutely decreased RV function following surgery.

At an intermediate-term follow-up after 3 months from MVR although 5 cases were lost at follow-up there was a continued improvement in the MV area and PAP there was a gradual improvement in RV function parameters but still RV-GLS and the free strain were lower in comparison to the control, other studies showed comparable means value of strain parameters with control but by the way, most of them was on BMV(5–7), to our knowledge our study was the first to evaluate changes in RV function before and after surgical MVR, actually the delayed improvement in RV function, in particular, GLS and free strain in our results could be due to the delayed surgical intervention and long history of PH and also the literature enumerated that RV performance may be influenced by some other factors following MV surgery. First, there was long-term RV adhesion to the thoracic wall followed by pericardial sac discontinuity. In addition, the geometric changes resulting from left ventricular unloading and RV reverse remodeling postsurgical could continue for some time [18]. There was a hypothesis that these modifications impact the RV systolic function, reducing longitudinal shortening. It has also been documented that there is an inability to reverse RV remodeling [19].

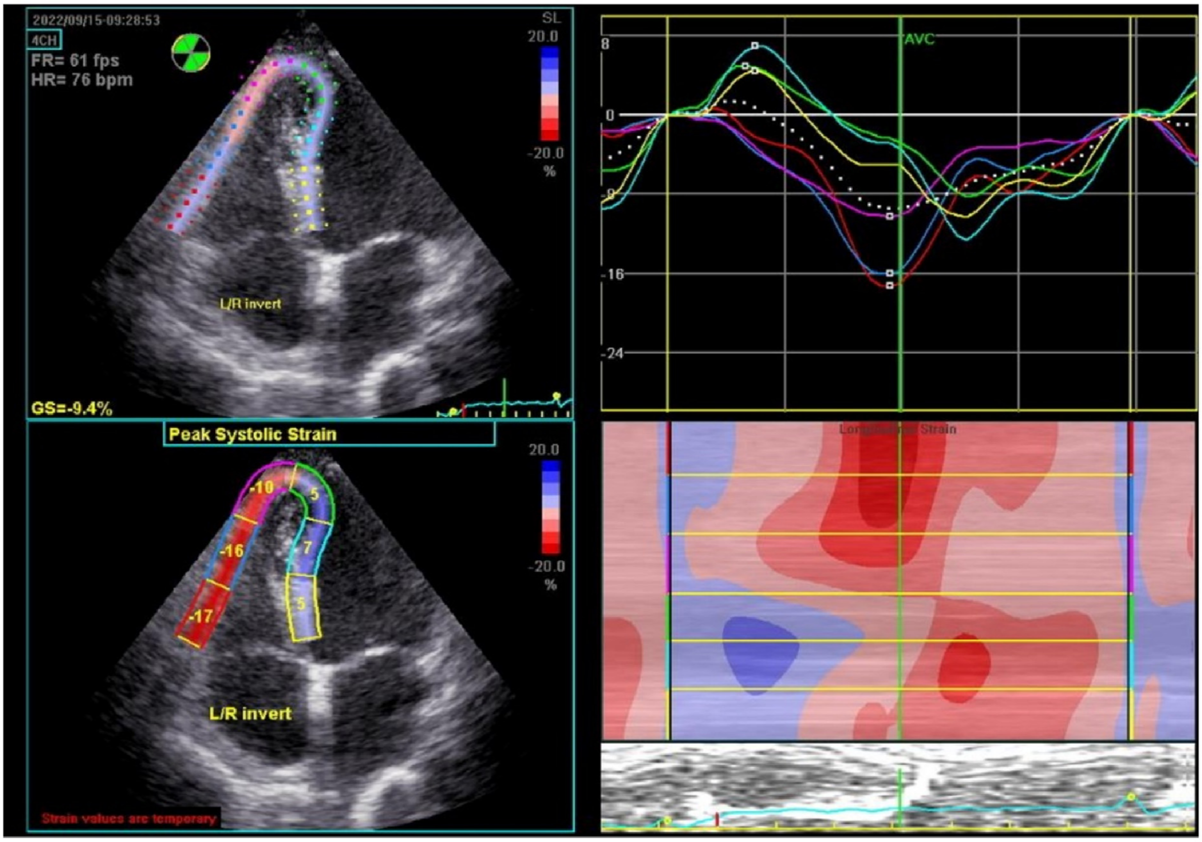


*Fig. 2. Case demonstration after 24 h of mitral valve replacement showing GS = −9.4% and free strain was calculated manually by averaging the basal, mid, and apical segments 17 + 16 + 10/3 = −14.3%.*

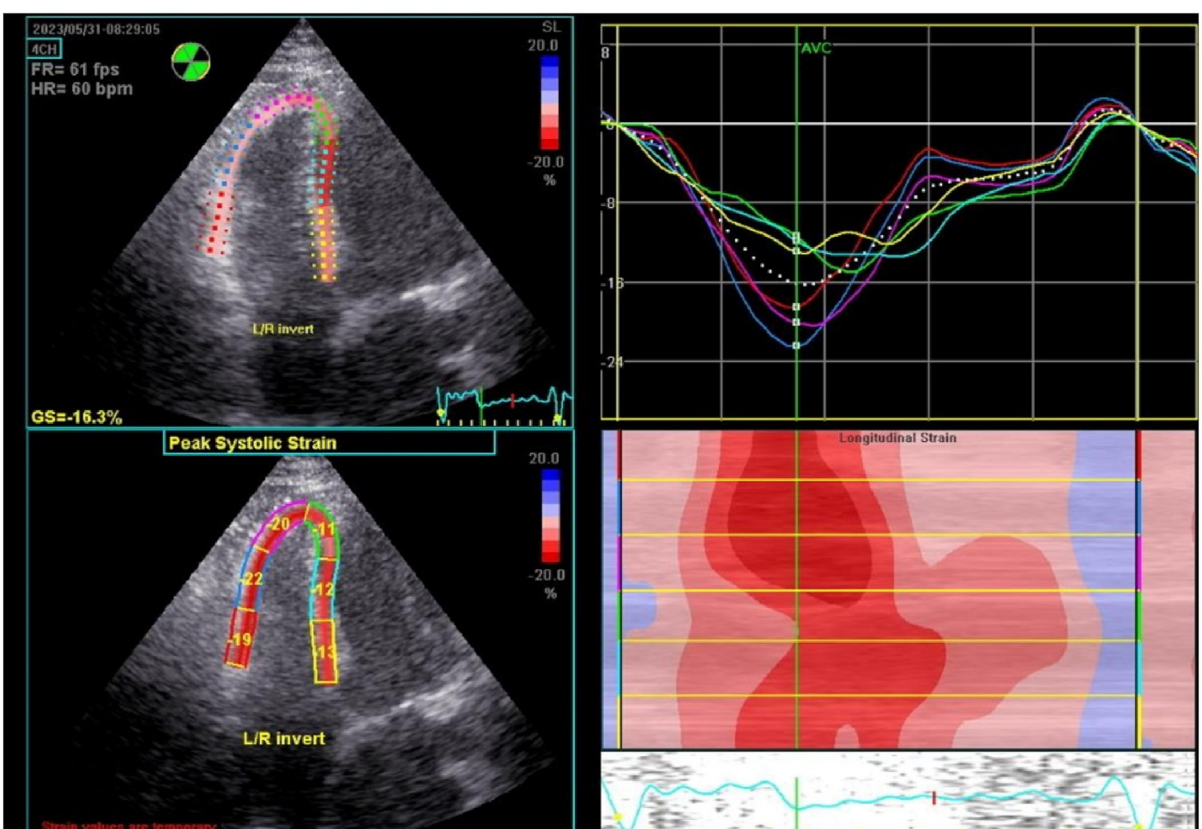


*Fig. 3. Case demonstration after 3 months of mitral valve replacement showing GS = −16.3% and free strain was calculated manually by averaging the basal, mid, and apical segments 17 + 16 + 10/3 = −20.3%.*

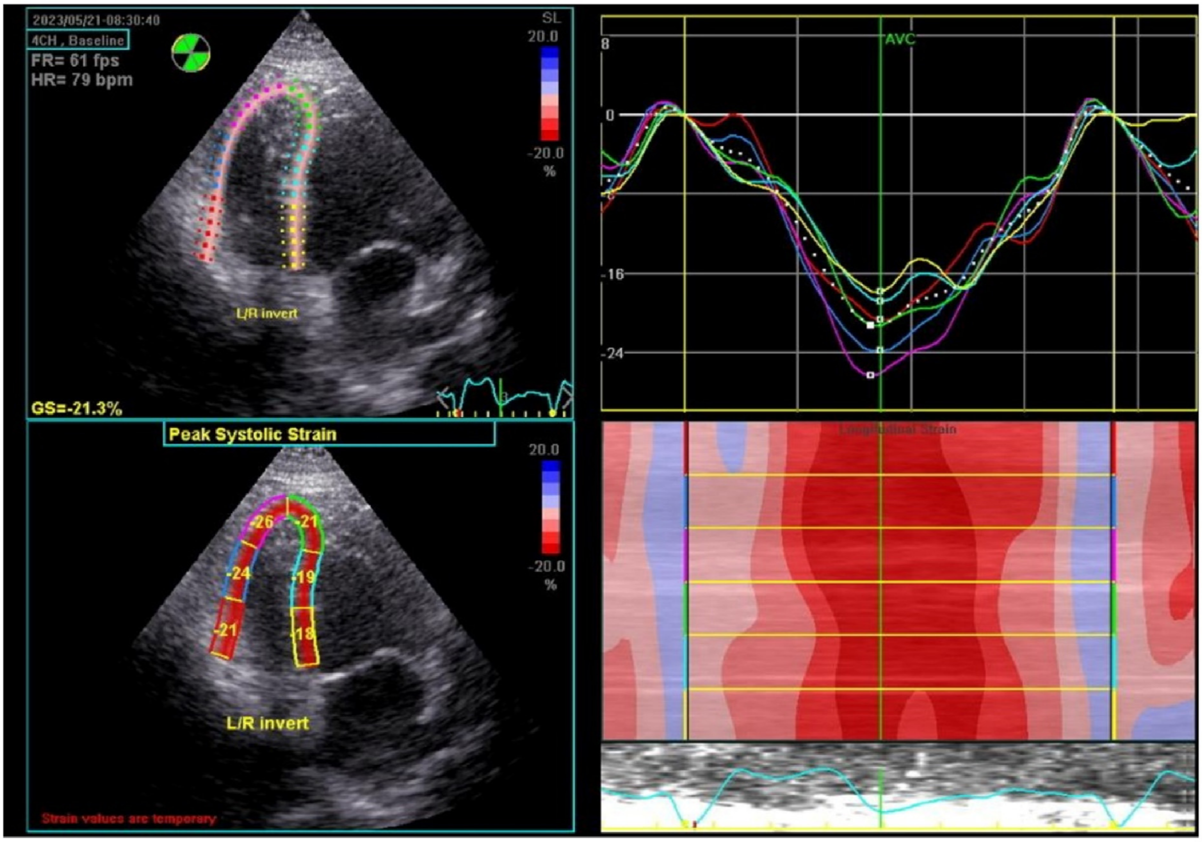


*Fig. 4. Control group showing GS = −21.3% and free strain was calculated manually by averaging the basal, mid, and apical segments 17 + 16 + 10/3 = −23.6%.*

### *4.1. Conclusions*

MS patients had impaired RV systolic function before MVR. There was a sharp deterioration in RV function 1 week postsurgery then RV systolic function recovered to some extent but was still far away from the control group. This condition could highlight the importance of MS intervention before latent RV myocardial dysfunction.

### *4.2. Limitations*

Our study had some limitations, first small sample size, second STE needed high image quality so cases with suboptimal image quality were excluded.

### *4.3. Recommendations*

It is recommended that future research with a larger sample size be conducted to validate our findings. To determine the long-term effects of MVR on RV function, long-term follow-up studies are recommended.

## Registration number

The study was approved by the General Organization for Teaching Hospitals and Institutes (GOTHI) with an IRB number coded as HAH00030, date: 9/27/2023.

## Ethical information

This work was carried out in accordance with the Declaration of Helsinki in which a The patients' written informed consent was obtained. The AL-AHRAR Teaching Hospitals Ethical Committee gave approval before the research started. The purpose and nature of the study as well as the risks were be explained to the patients or their relatives. The participants first guardians agreed that he/she would have the investigational nature of the study, its inherent risks and benefits. Confidentiality of data was assured in which Participants' information was replaced with research identification codes (ID Codes), data collection forms were be anonymous. Patients could withdraw from the study at any time and still get the full medical service with in the facility. Patients could refuse to participate and still get the standard and their right to know the research results were ensured.

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## Author contribution

Alaa Ramadan Youssuf and Eman H. Seddik are the main and corresponding authors diagnose, Conceived and designed the analysis. Ibrahim Afifi prepare the cases. Mohammad Morsy and Mohamed Mansour collect the data. Eman H. Seddik wrote the paper.

## Conflicts of interest

There are no conflicts of interest.

## Institutional review board (IRB) approval number

HAH00030.

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