

# Correlation between Pre-Operative Myocardial Fibrosis and Early Post CABG Dysrhythmia

## Abstract

**Background:** Cardiac magnetic resonance (CMR) imaging combines the assessment of both the functional and structural aspects of the heart in order to identify the existence, timing, and intensity of ischemic heart disease by analyzing the function of the myocardium and the movement of the heart wall. This study aimed to investigate whether preoperative myocardial fibrosis, measured by CMR imaging, may be used to predict the incidence of rhythm disturbances in the early postoperative phase after coronary artery bypass grafting (CABG) surgery.

**Methods:** Two groups of 92 patients who had CABG procedures performed were studied in this retrospective observational single site cohort study: There were 43 patients in Group A who had atrial or ventricular arrhythmia, and 49 patients in Group B who did not.

**Results:** There was no correlation between arrhythmia and non-arrhythmia group and age, sex, body mass index, risk factor, CMR timing before surgery, cross clamp time, bypass time, left ventricular end-diastolic volume index (LV EDVI), LV end-systolic volume index (ESVI), stroke volume index (SVI), LV ejection fraction (EF) and territory of scar and were positive correlation between both groups and scar ( $P < 0.001$ ). Scar% was an independent predictor of occurrence of rhythm disturbance ( $P = 0.002$ ) while LV EDVI, LV EF, LV ESVI, SVI, and presence of scar were not. Group A had a statistically significantly lower LV-EF% and lower LV-SVI compared to Group B. Group A had a higher scar percentage compared with group B and this was statistically significant ( $P < 0.001$ ). Rhythm disturbance occurred more often in patients with a scar percentage  $> 14.8\%$  ( $P = 0.0002$  and area under ROC curve (AUC) = 0.708).

**Conclusions:**CMR has evolved as a gold standard non-invasive imaging tool in cardiovascular medicine.Preoperative CMR imaging may be a promising tool for predicting postoperative cardiac arrhythmia after CABG.Our study showed that preoperative myocardial scarring >14.8%, as determined by CMR imaging, was predictive of early postoperative arrhythmia in patients undergoing CABG.

**Keywords:**Myocardial Fibrosis, Coronary Artery Bypass Graft, Dysrhythmia, Cardiac Magnetic Resonance, Ejection Fraction

UNDER PEER REVIEW

## Introduction:

In both developing and developed countries, coronary artery disease (CAD) ranks high among the leading causes of mortality. The American Heart Association estimates that 16.2 million Americans, defined as those aged 20 and above, suffer from cardiovascular disease. More than one-third of all deaths in adults over the age of 35 are caused by CAD. Over the last several decades, our understanding of CAD has made great strides<sup>[1]</sup>.

In recent decades, advancements in technology have strengthened the significance of noninvasive imaging in identifying, categorizing the risk, and treating individuals with ischemic heart disease. Cardiac magnetic resonance (CMR) imaging combines the assessment of heart function and structure to identify the presence, timing, and severity of ischemic heart disease. It evaluates factors such as myocardial function, wall motion, the occurrence and extent of myocardial ischemia, edema, and scar formation. CMR imaging of the myocardium in IHD is now accepted as a well-established procedure for its ability to provide reliable diagnostic and prognostic information<sup>[2]</sup>.

Correctly determining the presence or absence of viable myocardial muscle is crucial for effectively managing individuals with cardiac dysfunction. Viable muscle has the potential for contractile restoration. Consequently, a patient suffering from ischemic cardiomyopathy and ventricular dysfunction may see an enhancement in their functional capacity after cardiac revascularization. This improvement may lead to an increased chance of survival. Accurate detection of necrotic muscle, especially in cases of asymptomatic infarction (occult infarction), is crucial due to the potential for this tissue to serve as a foundation for ventricular tachyarrhythmia, a major contributor to sudden death<sup>[3]</sup>.

This study aimed to investigate whether preoperative myocardial fibrosis, as measured by CMR, may be used to predict the incidence of rhythm disruption in the early postoperative period after undergoing coronary artery bypass graft (CABG) surgery.

## Patients and Methods:

This research was a retrospective observational cohort study conducted at a single site. It included 92 patients of both sexes, aged between 20 and 75 years, who had undergone CABG. The research was conducted between 2014 and 2022, after clearance from the Ethical Committee of Tanta University Hospitals and Aswan Heart Center in Egypt. The patient or the patient's family provided a well-informed written consent.

Exclusion criteria were any preoperative rhythm abnormality and if the CMR exam was incomplete or aborted.

According to occurrence of arrhythmia during the hospital stay, patients were subdivided into two groups: Group A: patients who had arrhythmia either atrial or ventricular (n=43) and Group B: patients who did not have arrhythmia (n=49). Postoperative hospital stay varied from 1 day to 13 days with a mean of  $3\pm 2.58$ .

All patients were subjected to: history taking, clinical examination, operative and anesthesia notes regarding cardiopulmonary bypass, and cross clamp time) and standard resting 12 lead electrocardiogram (ECG) for rhythm analysis and continuous ECG monitoring by specialized monitors were done during the early post-operative course, daily in the first three days then every other day during hospital admission. The ECG analysis was mainly for arrhythmia detection either atrial arrhythmia including atrial fibrillation, atrial flutter, and supraventricular tachycardia or ventricular arrhythmia including sustained ventricular tachycardia, non-sustained ventricular tachycardia, and ventricular fibrillation.

### CMR

**Ventricular volumes and function:** Siemens Medical Systems' 1.5- T MRI scanner, the Siemens Magnetom Aera type, was used to carry out the CMR operation. Pictures were taken within one day after right cardiac catheterization (RHC). A retrospective electrocardiogram-gated steady-state free precession sequence was used to measure the systolic and diastolic

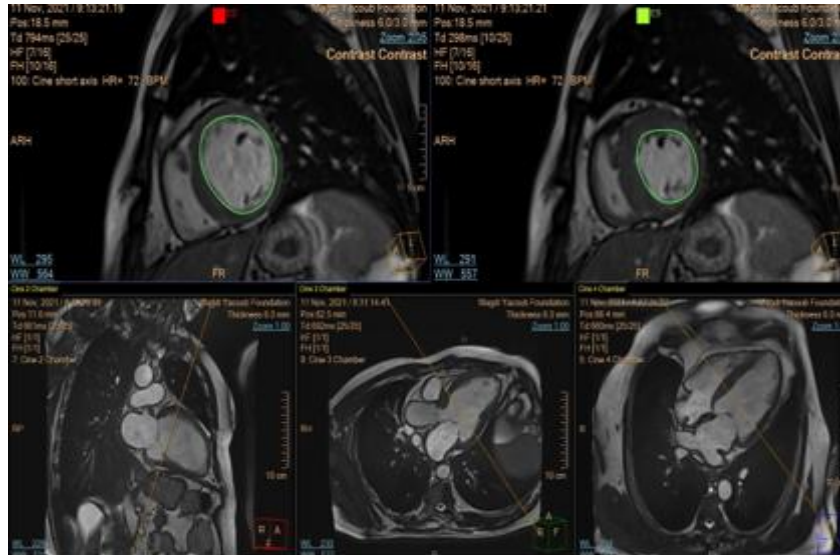
volumes while the subject held their breath. Horizontal long-axis (2- and 4-chamber) and short-axis (12-14 consecutive slice) pictures were acquired. Beginning from the base of the heart and reaching to its apex, these slices enveloped both ventricles. The parameters for the scan were as follows: a repeat time ranging from 3.2 to 3.8 ms, an echo length from 1.6 to 1.9 ms, a flip angle from 50 to 70°, a matrix size of 160 by 256, a field of view from 350 to 400 mm, a temporal resolution of around 25 ms, and a slice thickness of 6 to 8 mm without a gap between the slices.

**Delayed Contrast-Enhanced Magnetic Resonance Imaging:** Following the injection of a gadolinium-based contrast agent (Magnevist, Schering AG, Berlin, Germany; 0.2 mmol/kg) in the same direction as the cine short-axis images, dynamic contrast-enhanced (DCE) images were obtained for a period of ten to fifteen minutes. The images were captured by using a segmented inversion-recovery gradient-echo pulse sequence with the following parameters: repetition time / echo time = 4.01 / 1.25 milliseconds, flip angle = 15 degrees, matrix = 208 x 256, and a mean voxel size of 1.6 x 1.3 x 5.0 millimeters. 180-200 milliseconds was used as the inversion time (T1) for this experiment.

### **CMR analysis**

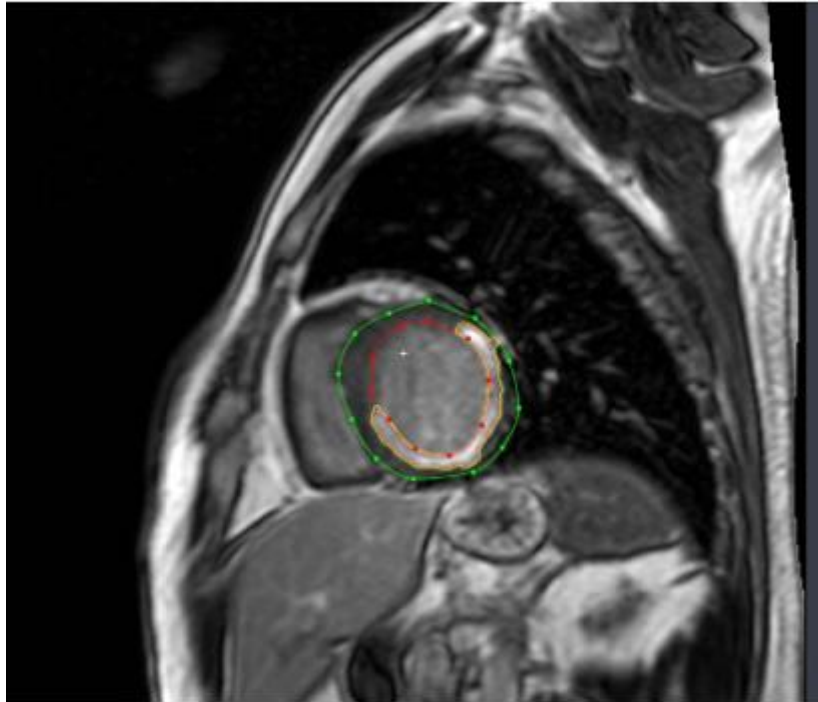
On an Intel desktop computer, each and every image was examined. For the purpose of evaluating the biventricular systolic function and the two-dimensional flow, the software tool known as Intellispace Portal, developed by Philips, was applied. In order to evaluate the biventricular systolic function, the endocardial contours of the left ventricle (LV) and the right ventricle (RV) were outlined in all cine short-axis data sections. This was done during both the end-diastolic and end-systolic phases of the heart's contractions. The measurements of end-diastolic and end-systolic volumes (EDV) were collected and then adjusted for body surface area (BSA) by using the Mosteller formula, which is as follows:  $(\sqrt{\text{Height [cm]} \times \text{weight [kg]}}/3600)$ . The end-systolic volume (ESV) was subtracted from the end-diastolic

volume (EDV) in order to arrive at the indexed ventricular stroke volume (SVI). After dividing the SV by the end diastolic volume (EDV), the ejection fraction (EF) was determined according to the formula. **Figure 1**



**Figure 1: CMR volume analysis**

**Fibrosis:** The level of fibrosis in each of the 16 myocardial segments was measured as part of the left ventricular global efficiency (LGE) evaluation. This was done by two experienced observers using the application (Segment CMR - Medviso). **Figure 2**



**Figure 2: The area of fibrosis by segment CMR-Medviso software in LGE images**

#### **Sample Size Calculation:**

The Epi-Info statistical software, produced by the World Health Organization and the Center for Disease Control and Prevention in Atlanta, Georgia, USA, was used to calculate sample size and power analysis. The precise version used was 2002. The criteria utilized for calculating sample size were as follows: 95% confidence interval. Preoperative myocardial fibrosis, as evaluated by CMR, may predict the occurrence of rhythm disturbance in the early postoperative period after CABG surgery. This prediction has a 70% sensitivity and a 10% margin of error (60-80%). The sample size, as calculated by the aforementioned criteria, was larger than 81. The sample size was increased to 96 patients to account for any missing data and improve data quality in the inquiry.

#### **Statistical analysis**

Utilizing the SPSS v26 program (IBM Inc., Chicago, Illinois, United States of America), the statistical analysis was carried out. Histograms and the Shapiro-Wilks test were used in order to ascertain whether or not the data are distributed in a normal fashion. The quantitative

parametric data were evaluated using an analysis of variance (ANOVA) test, followed by a Tukey post hoc test. The results were given as the mean and the standard deviation (SD). The Kruskal-Wallis test with an adjusted Bonferroni correction was used to compare the quantitative non-parametric data. The data were provided as the median and the interquartile range (IQR). Additionally, the Chi-square test was used to analyze the qualitative variables, which were reported in the form of frequency and percentage (%). In order to highlight the significance of scar tissue (percentage) found by CMR in determining the likelihood of developing rhythm abnormalities, a Receiver Operating Characteristic (ROC) curve was developed specifically for this purpose. For statistical significance, a two-tailed P value of less than 0.05 was regarded to be significant.

## Results:

Scar (%) can significantly predict the occurrence of rhythm disturbance ( $P=0.0002$  and  $AUC = 0.708$ ) at cut-off  $>14.8\%$  with 69.77% sensitivity, 65.31% specificity, 68.9% PPV and 78.2% NPV.

PPV: positive predictive value, NPV: negative predictive value, AUC: area under the curve

All demographics, medical history, cross clamp, bypass time, showed insignificantly different between both groups. **Table 1**

**Table 1: Data on demographics, risk factors, duration on cross clamp and bypass, total number of grafts between arrhythmia and non-arrhythmia groups, and combination surgery**

|                               |               | Arrhythmia group (n=43) | Non-arrhythmia group (n=49) | P     |
|-------------------------------|---------------|-------------------------|-----------------------------|-------|
| <b>Age (years)</b>            |               | 58.5(43 – 74)           | 47.5(20 – 75)               | 0.072 |
| <b>Sex</b>                    | <b>Male</b>   | 35 (81.4%)              | 44 (89.8%)                  | 0.248 |
|                               | <b>Female</b> | 8 (18.6%)               | 5 (10.2%)                   |       |
| <b>BMI (Kg/m<sup>2</sup>)</b> |               | 29.14 ± 4.4             | 27.49 ± 3.98                | 0.062 |
| <b>Risk Factors</b>           | <b>DM+HTN</b> | 21 (48.84%)             | 18 (36.73%)                 | 0.184 |
|                               | <b>HTN</b>    | 7 (16.28%)              | 6 (12.24%)                  |       |
|                               | <b>DM</b>     | 8 (18.6%)               | 7 (14.29%)                  |       |
| <b>Cross clamp time (min)</b> |               | 90(67.5 – 105)          | 92(64 – 119)                | 0.991 |
| <b>Bypass time (min)</b>      |               | 159(118 – 200)          | 150(121 – 180)              | 0.597 |

Distribution of the arrhythmia in the studied group was as described in **Table 2**

**Table 2: Arrhythmia of the studied group**

|                               |                            |                     |
|-------------------------------|----------------------------|---------------------|
| <b>Type of arrhythmia</b>     | <b>Ventricular</b>         | 20 patients (46.5%) |
|                               | <b>Atrial</b>              | 23 patients (53.5%) |
| <b>Ventricular arrhythmia</b> | <b>Sustained VT</b>        | 6 patients (30%)    |
|                               | <b>Non-sustained VT</b>    | 13 patients (65%)   |
|                               | <b>VF</b>                  | 1 patient (5%)      |
| <b>Atrial arrhythmia</b>      | <b>Atrial Fibrillation</b> | 19 patients (82.6%) |
|                               | <b>Atrial Flutter</b>      | 2 patients (8.7%)   |
|                               | <b>SVT</b>                 | 2 patients (8.7%)   |

VT: ventricular tachycardia, VF: ventricular fibrillation, SVT: Supraventricular tachycardia

CMR parameters (LV EDV, LV SV, SVI and LVEF), presence of scar and territorial distribution of myocardial fibrosis showed no significant difference between both groups.

The presence of scar showed significant difference between both groups ( $P < 0.001$ ). **Table 3**

**Table 3: CMR, scar parameters by CMR parameters of arrhythmia group and non-arrhythmia group**

|                                   | <b>Arrhythmia group<br/>(n=43)</b> | <b>Non-arrhythmia group<br/>(n=49)</b> | <b>P</b>          |       |
|-----------------------------------|------------------------------------|--|-------------------|-------|
| <b>LV EDVI (ml/m<sup>2</sup>)</b> | 111.17 ± 31.24                     | 100.5 ± 30.54                          | 0.106             |       |
| <b>LV ESVI (ml/m<sup>2</sup>)</b> | 70.76 ± 31.35                      | 59.54 ± 30.18                          | 0.088             |       |
| <b>SVI(ml/m<sup>2</sup>)</b>      | 40.5 ± 11.64                       | 40.73 ± 10.47                          | 0.922             |       |
| <b>LV EF (%)</b>                  | 38.33 ± 12.56                      | 43.33 ± 14.86                          | 0.091             |       |
| <b>Presence of scar</b>           | 40 (93.02%)                        | 46 (93.88%)                            | 0.868             |       |
| <b>Scar (%)</b>                   | 20.78 ± 12.72                      | 12.43 ± 9.3                            | <b>&lt;0.001*</b> |       |
| <b>Territory of scar</b>          | <b>LAD</b>                         | 11 (25.58%)                            | 13 (26.53%)       | 0.764 |
|                                   | <b>LAD-LCX</b>                     | 6 (13.95%)                             | 5 (10.2%)         |       |
|                                   | <b>LAD-LCX-RCA</b>                 | 1 (2.33%)                              | 0 (0%)            |       |
|                                   | <b>LAD-RCA</b>                     | 12 (27.91%)                            | 8 (16.33%)        |       |
|                                   | <b>LCX</b>                         | 1 (2.33%)                              | 7 (14.29%)        |       |
|                                   | <b>RCA</b>                         | 6 (13.95%)                             | 7 (14.29%)        |       |
|                                   | <b>RCA-LCX</b>                     | 3 (6.98%)                              | 3 (6.12%)         |       |

There was no correlation between (Arrhythmia and non-Arrhythmia group) and age, gender, BMI, risk factor, CMR time, cross clamp time, bypass time, LV EDVI, LV ESVI, SVI, LV EF and territory of scar and were positive correlation between (Arrhythmia and non-Arrhythmia group) and scar (%) ( $P < 0.001$ ). **Table 4**

**Table 4: Relationship between (Arrhythmia and non-Arrhythmia group) and other parameters**

|            | <b>r</b> | <b>P value</b> |
|------------|----------|----------------|
| <b>Age</b> | 0.189    | 0.072          |

|                                   |        |                   |
|-----------------------------------|--------|-------------------|
| <b>Sex</b>                        | 0.120  | 0.253             |
| <b>BMI</b>                        | 0.195  | 0.062             |
| <b>Risk Factor</b>                | 0.141  | 0.181             |
| <b>CMR time (mon)</b>             | 0.011  | 0.914             |
| <b>Cross clamp time (min)</b>     | -0.025 | 0.812             |
| <b>Bypass time</b>                | 0.023  | 0.827             |
| <b>LV EDVI (ml/m<sup>2</sup>)</b> | 0.172  | 0.106             |
| <b>LV ESVI (ml/m<sup>2</sup>)</b> | 0.181  | 0.088             |
| <b>SVI (ml/m<sup>2</sup>)</b>     | -0.010 | 0.922             |
| <b>LV EF (%)</b>                  | -0.179 | 0.091             |
| <b>Scar (%)</b>                   | 0.364  | <b>&lt;0.001*</b> |
| <b>Territory of scar</b>          | -0.019 | 0.858             |

In Multivariate regression, scar% was independent predictors of occurrence of rhythm disturbance (P value =0.002) while LV EDVI, LV EF, LV ESVI, SVI and presence of scar were not. **Table 5**

**Table 5: Multivariate regression of CMR parameters to predict the occurrence of rhythm disturbance**

|                              | Coefficient | Std. Error | P             |
|------------------------------|-------------|------------|---------------|
| LV EDVI (ml/m <sup>2</sup> ) | -0.36056    | 0.32948    | 0.2738        |
| LV EF (%)                    | -0.021263   | 0.055788   | 0.7031        |
| LV ESVI (ml/m <sup>2</sup> ) | 0.35534     | 0.33324    | 0.2863        |
| SVI (ml/m <sup>2</sup> )     | 0.39274     | 0.32783    | 0.2309        |
| Scar%                        | 0.086844    | 0.028344   | <b>0.002*</b> |
| Presence of scar             | -1.62121    | 0.98274    | 0.0990        |

## Discussion

In our observational study we have demonstrated that the percentage of myocardial scarring is the predictor to occurrence of arrhythmia in early post-operative period post GABG operation. The cut off point for occurrence of arrhythmia was at scar percentage of **14.8%** (**P=0.0002 and AUC = 0.708**). Lower EF % tends to be present in the arrhythmia Vs non-arrhythmia cohort but it is not statistically significant.

The clinical relevance of each arrhythmia is contingent upon several parameters, such as the underlying cardiac function, comorbidities of the patient, length of the arrhythmia, and the velocity of ventricular response. **Postoperative arrhythmia (POAs)** may be well-tolerated in

some individuals, whereas in others they might contribute to both morbidity and death, depending on the interplay of these variables<sup>[4]</sup>. Tachycardia-induced rapid ventricular rates may lead to both diastolic and later systolic dysfunction, resulting in a decrease in cardiac output and potentially causing hypotension or myocardial ischemia. Bradyarrhythmia, especially when accompanied by the impairment of atrial function, may significantly impact individuals with either systolic or diastolic ventricular failure<sup>[5]</sup>.

It's important to use imaging techniques to accurately diagnose, measure, and put these patients into risk groups, especially now that there are **effective treatment modalities available**<sup>[6]</sup>. Because of improvements in both technology and software, a current CMR scanner can give information about the structure and function of the myocardium, as well as the tissue's survival, circulation, and flow, all in a single 45–60 minute study<sup>[7,8]</sup>.

While most images are taken without the need for contrast chemicals, the use of Gd-CA, like Gd-DTPA (gadolinium diethylenetriamine penta-acetic acid), to show circulation flaws, microvascular ischemia, and areas of scar tissue/fibrosis is a big step forward [9]. Because Gd-CA is paramagnetic, it gives off a bright light when it is scanned. It doesn't change metabolism and is safe to give through a peripheral line as a single bolus. There is a very small chance that it will hurt the kidneys, so people who already have serious kidney damage should avoid getting it. Gd-CA can't get through the entire myocyte membrane because of how it is chemically made and how big its molecules are. It can, however, slowly spread and build up in the space between muscle cells or in myocytes where the cell membrane has been damaged. Most of the time, 0.1 to 0.2 mmol/kg (12 to 40 ml) is given<sup>[6]</sup>.

Some of the most common problems that can happen after CABG surgery are supraventricular (especially atrial fibrillation) and ventricular tachyarrhythmias (VT). Postoperative conduction disturbances also happen a lot, and sometimes a permanent

pacemaker is needed to fix the problem <sup>[10]</sup>. A number of studies have shown a strong link between atrial rhythms and both valve and nonvalvular CABG surgery<sup>[11, 12]</sup>.

Atrial fibrillation is the most prevalent kind of supraventricular tachyarrhythmias that may arise following CABG, with a reported incidence ranging from 5% to 40% <sup>[13]</sup>. There has been a rise in the occurrence of atrial fibrillation after CABG, even though there have been ongoing advancements in cardiac surgical methods. This tendency seems to be influenced, at least in part, by the introduction of cold potassium cardioplegia in the mid- to late 1970s for CABG procedures. The precise prevalence of postCABG atrial flutter is uncertain due to its typical co-occurrence with atrial fibrillation. Post CABG atrial fibrillation often develops within a timeframe of 24 to 72 hours after the surgery, with the highest occurrence seen on the second day after the operation<sup>[10]</sup>. Andreini et al. <sup>[14]</sup> stated that Ventricular arrhythmias of diverse causes were detectable on CMR imaging in a significant proportion of individuals who had no abnormalities on echocardiography. Also, Rizvi et al. <sup>[15]</sup> documented that Among the 90 patients who had CABG and had no previous history of heart failure (HF) or atrial fibrillation (AF), 34 patients (37.7%) experienced postoperative atrial fibrillation (PoAF) before being discharged from the hospital.

Noordman et al. <sup>[16]</sup> shown that in individuals who have survived a myocardial infarction, the extent of the scar's "border zone" area serves as an indicator for predicting ventricular arrhythmic episodes and long-term mortality. study. Appropriate implantable cardioverter defibrillator(ICD) shocks were associated with a higher event-free survival rate in patients with smaller overall scar masses compared to those with larger masses (>49.0 g).

Similarly, Buxton et al. <sup>[17]</sup> documented that total mortality and arrhythmic deaths/cardiac arrests occurred more frequently in patients with EF<30% than in those with EF of 30% to 40%.

Limitations of this study included that the sample size was relatively small. The retrospective nature of the study gave weak evidence conclusions.

### **Conclusions:**

Cardiovascular magnetic resonance (CMR) has evolved as a gold standard non-invasive imaging tool in cardiovascular medicine. It is a promising tool for predicting postoperative cardiac arrhythmia after coronary artery bypass graft (CABG) evidenced by significantly high scar tissue percentage in the arrhythmia group compared to the non-arrhythmia group. CMR serves as a valuable tool for prognostication in this setting.

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