International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Cardiac MR Imaging in the Assessment of Myocardial Viability Following Acute and Chronic Myocardial Infarction

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ABSTRACT

INTRODUCTION: Cardiac Magnetic Resonance Imaging is one of the evolving advanced imaging modalities for the assessment of myocardial viability. Following myocardial infarction, determining myocardial viability is crucial for predicting prognosis after percutaneous coronary intervention and plays a key role in decision-making in most cases.

MATERIALS AND METHODS: A prospective study of patients admitted to the Intensive Cardiac Care Unit of Gandhi Hospital from January 2014 to July 2015 with a clinical history of Acute Myocardial Infarction was taken up for cardiac Magnetic Resonance Imaging investigation(total 50 patients). A Cardiac Magnetic Resonance Imaging Study was performed in the Department of Radio-Diagnosis on a 1.5 Tesla Magnetic Resonance Imaging Machine (AVANTO of Siemens Limited). All patients received 10 mL of MULTIHANCE (gadobenate dimeglumine) intravenously after the precontrast study. Initial screening of all the patients was done by ECG and 2D Echo for evidence of myocardial infarction. Patients who are already on pacemakers, with previous h/o valve replacement surgeries, bypass surgeries, and other congenital cardiac anomalies were excluded.

RESULTS: The mean age of the study population was 54.9 years. The average age for males was 57.2 years, and the average age for females was 56.2 years. The most common abnormal finding was non-viable myocardium involving the LAD territory, followed by the RCA territory, findings that corresponded with coronary angiography and echocardiography results.

CONCLUSION: Delayed Enhanced Cardiac Magnetic Resonance Imaging (DE-CMR) is a highly sensitive and accurate procedure for evaluating myocardial viability following acute and chronic infarction.

KEYWORDS: DE-CMR1, Myocardial viability 2, non-viable myocardium 3, transmural infarct 4, Subendocardial infarct 5.

INTRODUCTION:

Cardiovascular disease is the single largest cause of death and one of the most prevalent diseases in developing countries. Globally, cardiovascular deaths represent 30% of all deaths (1). The prevalence of ischemic heart disease in India is extensive, both in rural and urban populations, and is the common cause of death in our country (2). Globally, 80 percent of those dying from cardiovascular diseases are in developing countries compared to the Western World (3). A comprehensive data of prevalence of ischemic

heart disease is 57.5 years in our country, which is 7-11years younger when compared to Western countries (4). This illustrates the significance and importance of identifying and preventing the disease, in addition to primary and secondary prevention, in our country. Imaging plays an important role in the identification of treatable diseases.

Viable hibernating myocardium can be identified by markers of myocardial viability and regions with contractile dysfunction by various imaging techniques. Identifying irreversibly injured myocardium from dysfunctional but viable myocardium, which can recover function, is of utmost importance for the management of cardiac patients. Revascularization of an infarcted area by percutaneous coronary intervention or coronary artery bypass grafting can only be justified if functional recovery will follow the intervention or if late outcomes and patient well-being can be improved after the procedure (5).

Concept of Myocardial Viability:

A cascade of events occurs in the process of regional or global myocardial ischemia. This cascade begins with disturbed myocardial vascularity, followed by a decrease in diastolic and, later, systolic function. Finally, this is followed by electrocardiographic changes, and the patient then develops typical symptomatic angina, which prompts the electrocardiographic test in the first place (5). There is a reduction in the contractile function following brief periods of hypoperfusion (6). The postischemic myocardial dysfunction that persists despite restoration of normal blood flow is termed stunning in the acute setting. Over time, contractile function gradually increases with the degree of transmurality of the ischemia. Hibernating myocardium shows abnormalities in contractile function at rest in the setting of chronic ischemia, which are potentially reversible with revascularization (7). There is an inverse relationship between the transmural extent of involvement and the likelihood of wall motion recovery following revascularization (8).

So, hibernating myocardium will improve or normalize after revascularization procedures. Stunned myocardium is myocardium with decreased function but intact cell membranes that does not show delayed enhancement on MR images. Cine MR imaging, usually performed in conjunction with delayed-enhancement MR imaging, shows akinesia in areas of myocardial stunning (9).

With this knowledge that identifying irreversibly injured (infarcted) myocardium from dysfunctional but viable, potentially salvageable myocardium is crucial for the management of cardiac patients, the availability of tests that differentiate between the two becomes very important (5).

Definite distinction between viable and non-viable myocardium, which is dysfunctional, therefore becomes necessary and crucial as it allows patients to benefit from the success of revascularization if they are shown by investigations to have a viable myocardium. Any of the risks, that the procedures such as revascularization are associated with, can thereby be avoided in patients who have nonviable myocardium and are unlikely to benefit from the surgery.

Only indirect methods are available to detect living myocytes in vivo in the clinical and research settings. These are

1. Recovery of contractile function following revascularization
2. Response to ionotropic stimulation (dobutamine or adenosine)
3. Presence of glucose metabolism (FDG PET imaging)
4. Presence of active cellular transport mechanisms (SPECT)
5. Presence of non-scarred (absence of scar) myocardium on cardiac MRI viability imaging with delayed enhancement.

AIMS & OBJECTIVES

- To evaluate the diagnosis of Myocardial Infarction.
- To assess myocardial viability in patients with acute and chronic Myocardial Infarction.

MATERIALS AND METHODS

A prospective analytical and descriptive study of 50 patients admitted to the Intensive Cardiac Care Unit of Gandhi Hospital with a clinical history of Acute Myocardial Infarction was taken up for cardiac Magnetic Resonance Imaging investigation. All patients were given 10 mL of MULTIHANCE (gadobenate dimeglumine) intravenously after the pre-contrast study.

The study lasted 18 months, from January 2014 to August 2015. The CMR Study was performed in the Department of Radio-Diagnosis on a 1.5 Tesla Magnetic Resonance Imaging Machine (AVANTO, Siemens Limited). Diagnosis drawn based on MR findings correlated with clinical, ECG, 2D Echo, cardiac enzymes, and coronary angiography.(Figure-1)

INCLUSION CRITERIA

All patients admitted for the management of MI who are initially investigated with ECG, 2D Echo, and coronary angiography are included.

EXCLUSION CRITERIA:

Patients who are already on pacemakers, with previous h/o valve replacement surgeries, bypass surgeries, and other congenital cardiac anomalies were excluded.

TECHNIQUE:

An MR scan was performed on a 1.5T MR scanner (AVANTO of Siemens Limited). Electrocardiogram triggering was performed with a vector-ECG set-up. Subjects were examined in the supine position. Morphologic images in the multislice cardiac short axis, four chamber long axis, three chamber, and two chamber long axis, were acquired by using tru FISP, HASTE cine images (slice thickness 5.0mm, repetition time 3.4ms; echo time 1.7ms; flip angle 60°; matrix 256. Myocardial scar was assessed on CE multislice short- axis, long-axis, and four-chamber views, obtained 10 minutes after intravenous bolus injection of 0.2mmol gadolinium/kg body weight (MULTIHANCE).

INTERPRETATION OF CARDIAC MRI:

The 17 cardiac segment model, as described by the American Heart Association (AHA), was used to characterize the extent of hyperenhancement, wall motion abnormalities, or other lesions that may be identified. An area of ischemic myocardium appears as a regional wall-motion abnormality on cine MR images. The infarcted tissues show segments with variable transmurality and hyperenhancement on post-gadolinium-DTPA delayed scans.

The LV ejection fraction was calculated using the dedicated software of the Siemens 1.5 T MRI machine. The software used is Argus (Siemens, Erlangen, Germany). This software is already validated, widely used internationally, and approved by the SCMR (Society for Cardiovascular Magnetic Resonance Imaging). The software allows us to outline the endocardium in multiple short-axis sections of both ventricles at end diastole, after which the ejection fraction, stroke volume, and cardiac output are automatically generated.

Wall motion abnormality was scored both qualitatively and quantitatively:

- Normal
- mild or moderate hypokinesia
- Severe hypokinesia
- Akinesia, and
- Dyskinesia

Quantitative wall motion abnormality will be scored by the formula: (end-systolic wall thickness - end-diastolic wall thickness) * 100 / end-diastolic wall thickness.

To quantify the size of infarcted myocardial tissue, the myocardium was divided into 17 equiangular segments using the American Heart Association's segmentation of the left ventricular myocardium. The dimensions of the infarction area within each segment were estimated visually.

SCORING OF INFARCT based on enhancement pattern.

0 - 0% Hyperenhancement in a RWMA

1 - Hyperenhancement of 1 to 25% thickness of the wall in the myocardium with RWMA

2 - Hyperenhancement of 26 to 50% thickness of the wall in the myocardium with RWMA

3 - Hyperenhancement of 51 to 75% thickness of the wall in the myocardium with RWMA

4- Hyperenhancement of 76 to 100% thickness of the wall in the myocardium with RWMA

Statistical software: SAS 9.2, SPSS 15.0, and Windostat Version 9.2 from Windostat Services were used for data analysis, and Microsoft Word and Excel were used to generate graphs, tables, etc.

RESULTS AND DISCUSSION:

A total of 50 patients who presented with symptomatic ischemic heart disease and required complete evaluation, including coronary angiography and cardiac MRI for viability of myocardium, were recruited in the study.

The mean age of the study population was 54.9 years. The average age for males was 57.2 years, and the average age for females was 56.2 years. 34% of the patient population was aged 60-70 years. The mean age of the study population correlated with the population suffering from ischemic heart disease in Western and other developed nations. The predominant gender in the study was male (80%), with the remaining 20% being females. This gender bias in our study can be attributed to males having more risk factors than females and seeking medical help more than females due to various reasons, such as being the bread earner of the family, etc.

The common comorbidity seen in the study was hypertension, which was observed in 55% the study population, and diabetes mellitus in 52% of them. Dyslipidemia was observed in 42% of the population, a history of smoking was seen in 36%, and 64% were nonsmokers. Acute MI was noted in 59.6% of the study population, and chronic MI in 40%, of which 6 (22.5%) and 4 (23%) were viable, respectively.

The literature concludes that a combined DE and T2-weighted MR approach is a clinically reliable tool for differentiating acute from chronic MI. Although DE is a powerful marker of non-viability and therefore detects infarction at any disease stage, a transmural high T2 signal indicates the acute event (10).

Both acute and chronic injuries present as regional wall motion abnormalities on echocardiography; wall thinning is a feature of chronic infarcts (11). This finding is not observed in non-transmural infarcts (12). In the absence of viable myocardial cells, both acute myocardial infarction and chronic MI fail to uptake radioactive tracers in radionuclide imaging and thus appear as fixed defects (13). Finally, although DE

cardiovascular MRI accurately detects irreversible myocardial injury, both acute MI and chronic MI exhibit DE regardless of their age (14, 15, 16).

Choi et al (15) in their study of 24 patients with first infarction and successful early revascularization, found that the transmural extent of enhancement 7 days after the acute event was predictive of recovery of wall thickening and ejection fraction at 8–12 weeks.

Gerber et al performed contrast and tagged MRI on 20 patients at 4 days and at 7 months after acute myocardial infarction. Using receiver operating characteristic analysis, these authors found that the absence of hyperenhancement had a sensitivity and accuracy of 82% and 74%, respectively, for predicting functional recovery, whereas the absence of early first-pass hypoenhancement had little value in predicting functional recovery (17).

Based on electrocardiographic findings, anterior wall MI was observed in 67% of cases, inferior wall MI in 22%, inferoposterior MI in 6%, lateral wall MI in 5%, and anterolateral MI in 1% of the study population. In the study, the total number of AWMI cases was 22, of which 19 had nonviable segments in the corresponding territory, and 3 had viable segments. 8 cases were from IWMI, of which 6 and 2 had nonviable and viable segments, respectively, in the corresponding territories. LWMI, Inferoposterior, anteroinferior MI constitutes 1 case each, which had nonviable segments in the corresponding territory on LGE MRI. Out of 2 cases of anterolateral MI, 1 had nonviable segments, and another had viable segments in the corresponding territory.

Pearson's correlation was generated for the values of ejection fraction measured by echocardiography and MRI short-axis cine images. Pearson's correlation was found to be 96.8%, with a p-value of 0.0001, which is statistically significant.

Using cine MRI to study wall contractility, 26 cases showed akinesia, 12 showed hypokinesia, 10 showed mixed akinesia/hypokinesia, and only 2 were normal. Akinesia was predominant in both acute and sub-acute MI (60% and 30% respectively, while most chronic MI showed mixed akinesia/hypokinesia (40.4%) Wall thinning in the area of myocardial infarction was depicted in 16 cases. Most cases of chronic and subacute MI showed thin walls. On the other side, most cases of acute MI (83.3%) showed normal wall thickness.

A blood clot within the left ventricular cavity was seen in only 9 cases; most (5) had chronic MI (P=0.86). Detection of the obstructed coronary artery was inferred from the distribution of the infarcted myocardium. The myocardial tissue supplied by each artery was divided into 8 segments, so the amount of nonviable tissue was expressed as a number out of 8, for example, 2/8, 3/8…. In the study population, the LAD territory was the most common coronary artery involved on DE-MRI, accounting for 52% (23) of cases; 4 cases had viable segments, and 19 had nonviable segments in the corresponding territory (Figure 3).LAD+RCA territory (Figure 4)constitutes 8 cases, of which 1 had viable segments, and 7 had nonviable myocardium in the corresponding territory.13%(5) of the cases showed involvement of RCA territory (Figure 5), of which 2 cases had viable myocardium and 3 cases had nonviable myocardium in the corresponding territory. In all cases with LCX, LCX+RCA (Figure 6) territory involvement, the corresponding territory showed nonviable myocardium, and 7% (4) of the cases were viable. Non-viable tissue was seen in 55 cases, including acute, subacute, and chronic MI, with a p-value of 0.31.

On correlating the findings from ECG, DSA, and DE MRI, 22 cases were diagnosed as AWMI based on ECG and clinical features, and 15 cases had >50% stenosis on DSA (Figure 7). Of 15 DSA cases showing significant stenosis, 13 had corresponding territory involvement, and 2 had other territory involvement on DE-MRI.

Based on the Kappa agreement test to see whether there was significant agreement between the presence of disease in an artery identified on coronary angiography and the corresponding irrigation segment on cardiac MRI, there was no statistically significant agreement between the two groups in the case of RCA and LCX, moderate agreement was seen in the case of LAD territory, although we expected 100% agreement. This can be explained by the fact that any degree of disease, including minimal or minor disease identified on coronary angiography, was recorded as a diseased vessel. This vessel occlusion, however, is not yet significant enough to cause definite myocardial infarction, as evidenced by delayed enhancement on the viability scan.

This finding likely highlights the limitations of cardiac MRI in identifying minor coronary artery disease when used in isolation. It also highlights that coronary angiography, in conjunction with viability MRI, will provide the most information to support decision-making and patient management.

When a paired t-test was performed to analyze the association between the degree of occlusion in a diseased coronary vessel and the involvement of the corresponding myocardial segment, we found a statistically significant association only between right coronary artery occlusion and the presence of an infarct in the myocardium (p-value = 0.0001). This means that the association between a diseased right coronary artery and the occurrence of an infarct in the irrigation territory in the myocardium is statistically significant. However, the same could not be said for the left circumflex artery or the left anterior descending artery in our study. But as the percentage of stenosis increased, the degree of transmurality also increased in the corresponding territory, and as the percentage of stenosis on DSA increased, the number of nonviable segments also increased in the corresponding territory.

CONCLUSION:

We conclude that ECG is the screening modality of choice, and Coronary angiography, along with DE-MRI in selected cases, proved to be the investigation of choice for predicting functional improvement post-revascularization. Management Protocol consisting of a combination of cardiac MR viability and coronary angiography will give all the information required for functional recovery, and also, MRI is good for follow-up studies as there is no risk of radiation exposure and is easy for comparison.

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Figure-1-Flow chart indicating the overview methodology of the study.

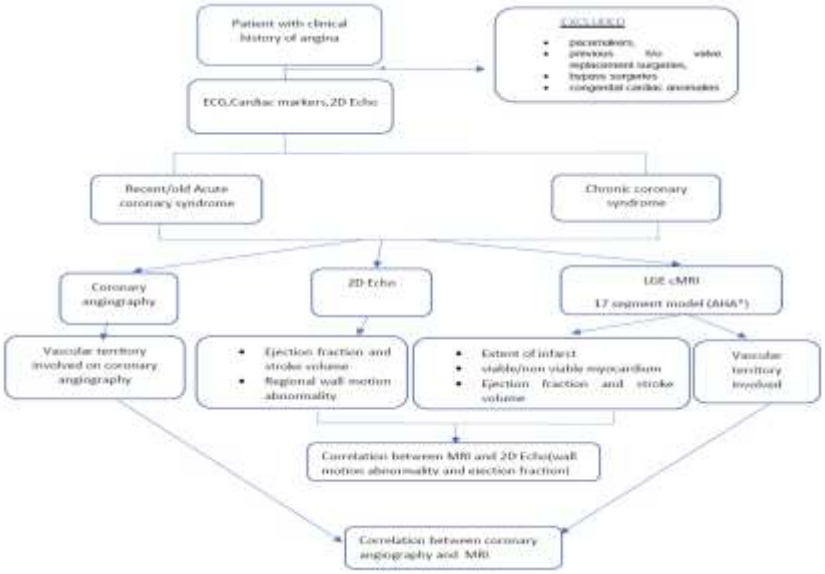


Figure-2: Left Ventricular Ejection Fraction. (ECHO VS MRI)

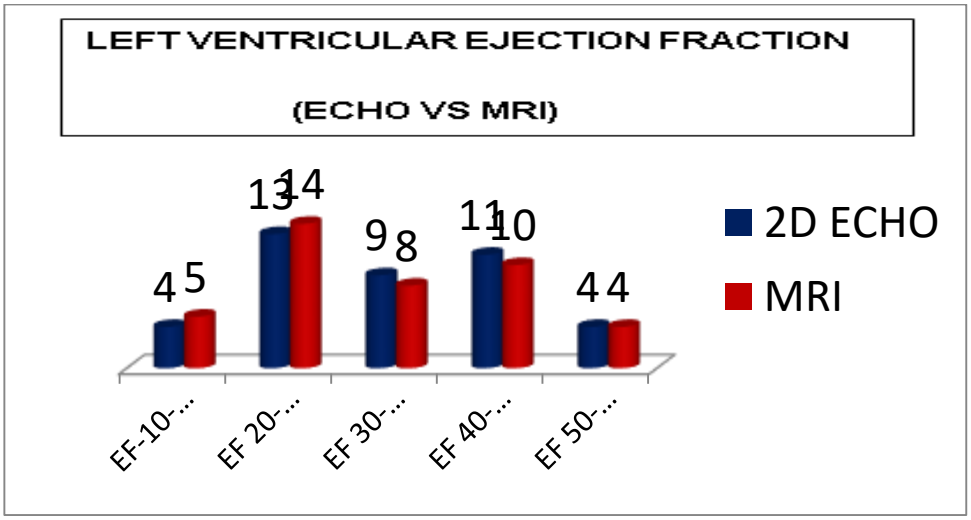


Figure 3: A 60-year-old male was a known case of old AWMI with thinned out anterior IVS, severe LV systolic dysfunction, and mild MR on 2D Echo. Angiography demonstrated 20% stenosis of the LMCA, 90% stenosis of the LAD, WNL of the LCX, and 90% stenosis of the RCA. Plain and DE-CMR images in short axis and horizontal and vertical long axis views showing dilated LV apex, thinning of myocardium at IVS, anterior wall in mid body region, and delayed hyperenhancement involving 50-75% of the myocardial thickness in LAD territory involving 5 segments.

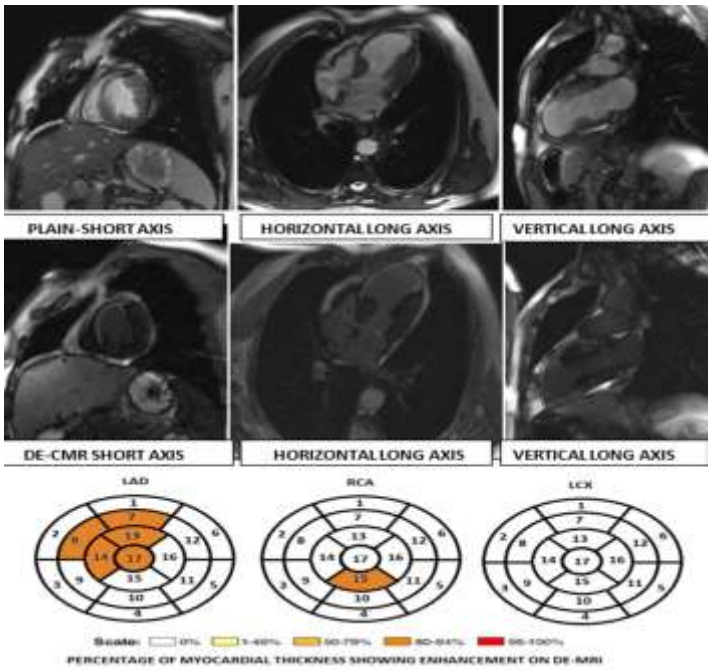


Figure 4: A 63-year-old male presenting with chest pain and SOB diagnosed as acute anterior and lateral wall MI on ECG with EF-43% on 2D Echo. Angiography showed- LMCA 20% stenosis, LAD -50%, RCA -99%, LCX -50%. Plain and DE-CMR images in short axis and horizontal and vertical long axis views showing delayed transmural hyperenhancement in the midbody region involving the anterior segment and interventricular septum associated with dilated LV and apical clot.

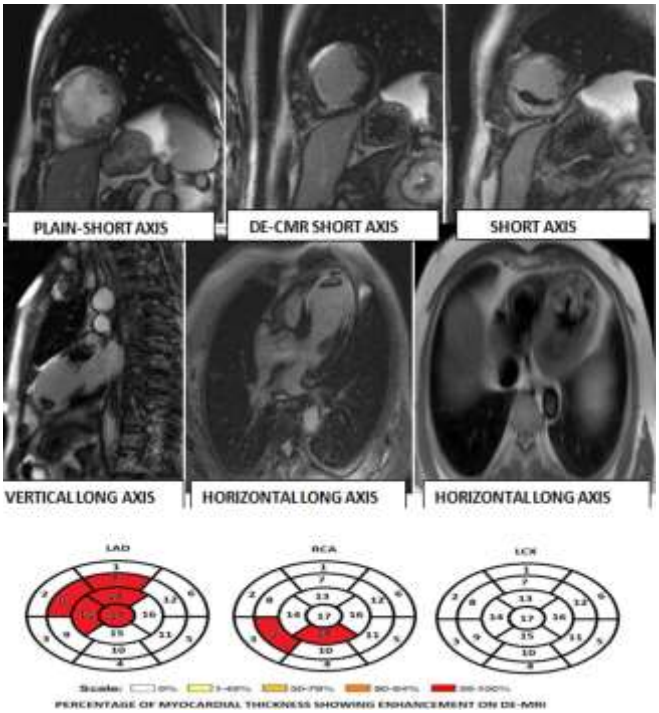


Figure 5: A 63-year-old male presented with chest pain and was diagnosed with Inferior wall MI with hypokinetic inferior wall, inferior IVS, posterior wall, and mild to moderate LV systolic dysfunction on 2D Echocardiography. Angiography showed LMCA WNL, LAD 5O% RCA 90%, and LCX 50%. Plain and DE-CMR images in short axis and horizontal and vertical long axis views showing 75-100% of the myocardial thickness involvement in RCA territory involving the inferior wall, inferoseptal location in the midbody and base region. bulls eye plot showing transmural nonviable myocardium in the midbody and base region.

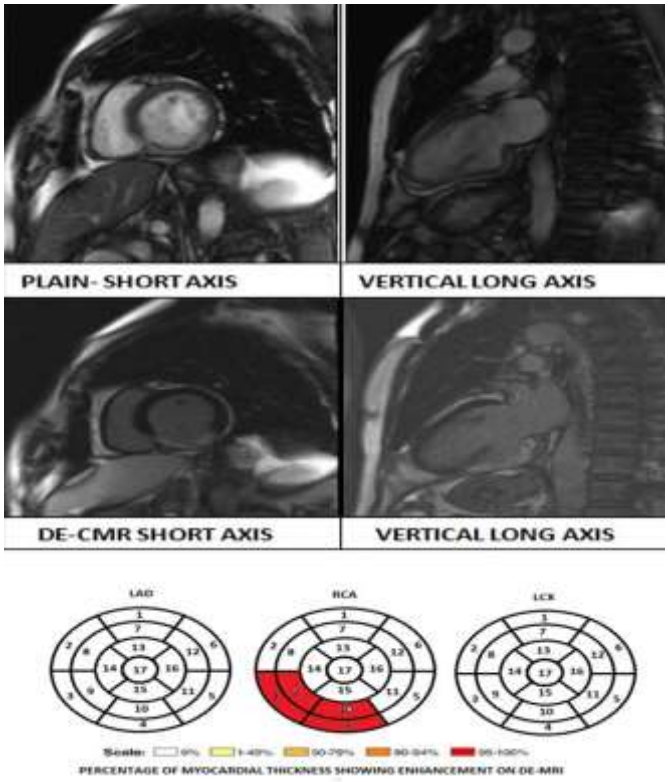


Figure 6: A 60 Yr old male presenting with SOB and chest pain diagnosed as Inferior Wall MI, with Angiography showing LMCA WNL, LAD 70%RCA 100%, LCX WNL. Plain and DE-CMR images in short axis and horizontal and vertical long axis views showing delayed hyperenhancement involving 50-75% of the myocardial thickness in RCA territory(inferior wall) in midbody and base region, and in the LCX territory.

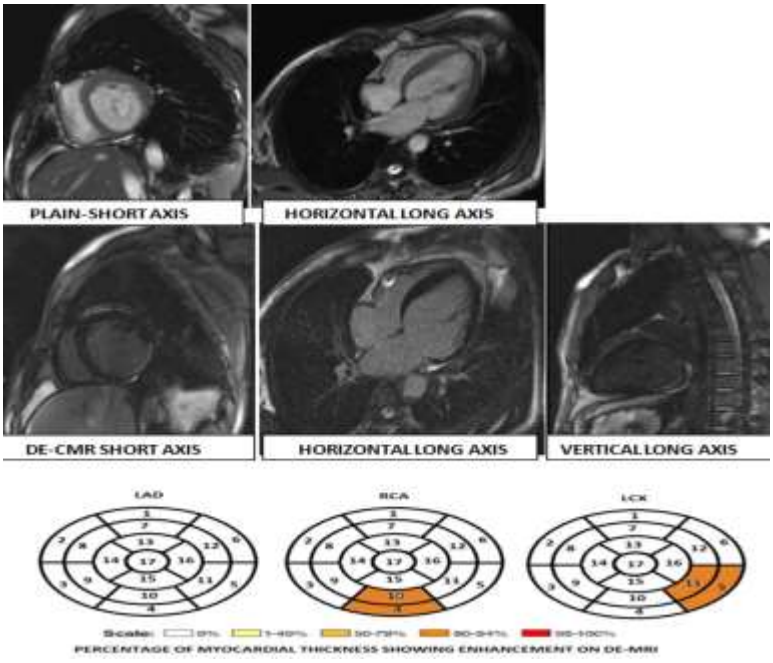
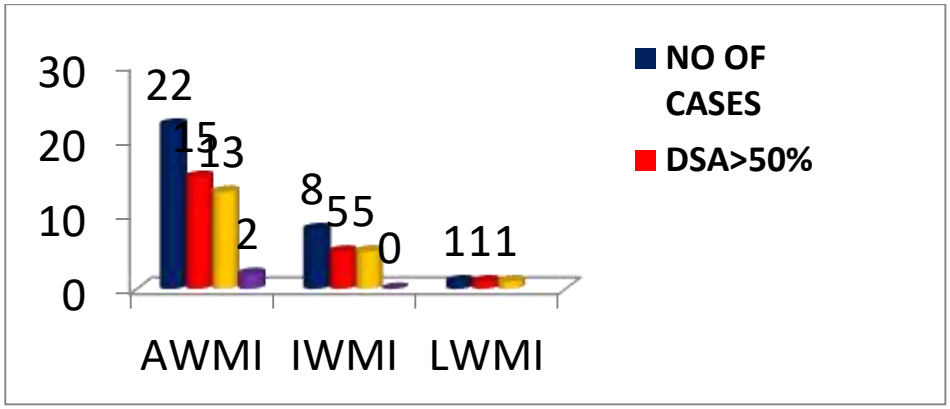


Figure-7: Bar diagram showing types of MI. Number of cases showing >50% stenosis on DSA, number of cases detected on MRI in the corresponding territory, and other territories.


30
20
10
0
22
15
13
2
8
5
5
0
1
1
1
AWMI
IWMI
LWMI
NO OF CASES
DSA>50%