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Comparision of Myocardial Viability Assessment Between Cardiac Magnetic Resonance Imaging and Single Photon Emission Computed Tomography in Patients with Coronary Artery Disease

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ABSTRACT

Objective: To assess the myocardial viability on cardiac magnetic resonance imaging compared with single photon emission computed tomography scan in patients with coronary artery disease.

Study Design: This study was cross sectional study.

Place and Duration of Study: Cardiac Magnetic Resonance Imaging and Nuclear Medicine Departments of a Tertiary Cardiac Care Center of Rawalpindi Pakistan, from Dec 2021 to May 2022.

Methodology: This study was cross sectional study conducted from December 2021 to May 2022 at Cardiac Magnetic resonance imaging and Nuclear Medicine departments of a Tertiary Cardiac Care Center of Rawalpindi Pakistan. Thirty patients (n=30) with coronary artery disease were selected using non-probability consecutive sampling technique to determine the viable myocardium using cardiac magnetic resonance imaging (CMR) and single photon emission computed tomography (SPECT) scan. Patients with left ventricular dysfunction having ejection fraction equal to or less than forty-five percent and coronary artery disease were included.

Results: Using 20 segment models, the mean number of viable segments in SPECT scan and CMR were 16.6±3.18 and 15.47±3.84, respectively while the non-viable segments were 3.4±3.1 and 5.17±4.6, respectively. There was statically little difference in results of Single-photon Emission Computerized Tomography and Cardiac Magnetic Resonance Imaging to determine viable myocardium (p<0.05).

Conclusion: Assessment of myocardial viability has keen role in diagnostic and prognostic work up of coronary artery disease patients who are candidates of revascularization. Stunned and hibernating myocardium are two states of reversible myocardial dysfunction. Revascularization can improve the regional and global contractile dysfunction after an old infarct. PET scan is gold standard for assessing myocardial viability followed by CMR. Studies showed a considerable variability in results of CMR and SPECT scan in assessing myocardial viability. CMR is safest imaging technique and its accuracy is closest to that of PET. Therefore, CMR is considered more reliable modality to access viable myocardium.

Keywords: Cardiac Magnetic Resonance Imaging, Coronary Artery Disease, Hibernating myocardium, Left Ventricular dysfunction, Myocardial viability, Stunned myocardium.

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INTRODUCTION

Coronary artery disease (CAD) is indeed the principal cause of developing heart failure and is the leading cause of morbidity and mortality in population of modern world.[1,2] In 2015 the death toll due to CAD was 8.9 million worldwide.[3] Every fourth middle aged individual in Pakistan is affected by CAD.[4] The etiology of CAD is multifactorial, including modifiable and non-modifiable risk factors. Amongst all, hypertension, smoking, obesity, diabetes mellitus and hypercholesterolemia are major risk factors.[5] Social inhibition, emotional distress, type D personality and dietary preferences are other considerable risk factors of CAD.

Great efforts are being made to timely diagnose, treat and prevent fatal outcomes of CAD. The major effects of morbidity and mortality of CAD have been significantly reduced with the utility of anti-thrombolytic and percutaneous coronary interventions (PCI) in the last few decades. Ischemic myocardium can recover contractile function after revascularization in conjunction with optimal medical therapy (OMT).[6] Contrary to old assumptions, now it is evident that left ventricular (LV) dysfunction is not a permanent state of contractile dysfunction after an old myocardial infarction. In patients of CAD the regional and global ventricular function of the affected myocardium can be adorably improve after revascularization either with coronary artery bypass surgery (CABG) or with PCI. This concept of functional resurrection of infarcted myocardium after reinstitution of blood flow was first introduced by Dr George Diamond in 1978 as

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"Myocardial Hibernation". Later on Dr Shahbudin Rahimtoola in 1989 made this concept more comprehensible and intelligible. Moreover, Braunwald and Rutherford laid stress on its early detection and rectification by revascularization.[7] Hibernation is a reversible state of reduced myocardial contractility with preserved cellularity as a result of sustained reduction in myocardial blood supply. Initially it was thought that the blood supply of a myocardial segment is reduced enough by atherosclerotic plaque to depress its contractility while leaving its viability due to minute blood supply. Rahimtool described a classic case of hibernating myocardium as a consequence of CAD with depressed LV ejection fraction (EF) of 37% that improved to 51% after administration of nitroglycerine and to 76% after CABG. "Stunned myocardium" is another reversible state of myocardial contractile dysfunction described by Braunwald and Kloner in 1982. They described myocardial stunning as Hit, Run and Stun i.e. a myocardial segment is affected by a brief episode of severe ischemia followed by reperfusion reducing its contractility for a long period of time without causing permanent damage.[7] Stunning occurs due to brief abrupt and severe coronary blood flow occlusion followed by reperfusion. This rapid reduction of blood flow causes contractile dysfunction for a time being even after its recovery. Reperfusion results in calcium overload that temporarily damages the myocardial contractile proteins. Many experimental models showed that these types of reversible myocardial dysfunction can be rectified by revascularization in terms of chronic coronary artery stenosis.[8-10] Therefore, It is very important to recognize viable myocardium in patients with CAD to improve their quality of life by revascularization techniques.

Assessment of myocardial viability in LV dysfunction is of paramount importance as all future intervention decisions are based on viability studies. Falsely identified scarred non-viable myocardium can significantly impose grave impact on lives of symptomatic patients who could otherwise be benefited from revascularization. Various imaging methods can be used to determine myocardial viability including Ventriculography, Cardiac Positron Emission Tomography (PET) scan, Cardiac Magnetic Resonance imaging (CMR) and 99 mtc-sestamibi methoxyisobutylisonitrile single photon emission computed tomography (SPECT) scan. Each modality has advantages over others which are tailored according to individual patient circumstances. Venrticulograhy is the most primitive imaging method and is not used for assessment of myocardial viability nowadays. PET scan is the renowned and well proven imaging modality for the assessment of infarct size but it is not widely available in our part of world. However, CMR and SPECT scan appeared to be good substitutes for differentiation viable and non-viable myocardium. By virtue of its availability for a long time, SPECT scan is being preferred and more commonly utilized method with good results. Today, CMR takes advantage over SPECT scan due to high accuracy, reproducibility, high spatial resolution and lack of exposure to hazardous ionizing radiations.[11]

Hence, the aim of this study was to validate the viable and non-viable myocardium among patients with CAD using CMR and SPECT scan and enhance awareness of specialist dependent population in absence of PET.

METHODOLOGY

A cross sectional study was conducted at two departments, Cardiac MRI and Nuclear Medicine department, of a Tertiary Cardiac Care Center of Rawalpindi Pakistan.

Sample Size: All the consecutive patients who underwent daignostic procedures were selected as study participants and they accounted to n=30

Inclusion Criteria: Patients with ventricular dysfunction with ejection fraction of ≤45% and having coronary artery disease.

Exclusion Criteria: Those patients who recevied metallic implants (non-compatible to 3.0T MRI) and presented with myocarditis, non-ischemic dilated cardiomyopathy, Valvular heart diseases and renal failure were excluded from the study.

Study was conducted after the IERB letter # 24/12/R&D/2021/124 from December 2021 to May 2022. A total of 30 patients were selected using non-probability sampling technique who underwent both the nuclear and MRI scans.

DDD gamma CorCam diagnostic was used for SPECT scan. Patients were restrained not to drink any caffeine containing beverages 6 hours prior to Tc-99m sestamibi injection. They were instructed to discontinue beta blockers and calcium channel blockers 48 hours before testing and nitrate compounds 6 hours before testing. A resting scan was performed after 10 mins of Tc-99m sestamibi 10mCi using a 15% window centered over the 140 keV photopeak. After 1.5 hours of first dose, sublingual nitroglycerine was given and blood pressure was recorded. A second dose of Tc-99m sestamibi 30 mCi was injected at peak exercise and again images were taken after 30 mins using a 15% window centered over the 140 keV photopeak. Data was analyzed on 4DM and Cedar Sinai Quantitative Gated and Perfusion SPECT that describe viable segments and volumetric analyses according to 20 segment model of heart as shown in Figure-1.

Siemens 3.0 Tesla Magnetom skyra with 18 channel dedicated cardiac coils was used to acquire CMR images. Imaging protocol included steady state free precession (SSFP), parametric mapping, first pass perfusion, and late gadolinium enhancement.

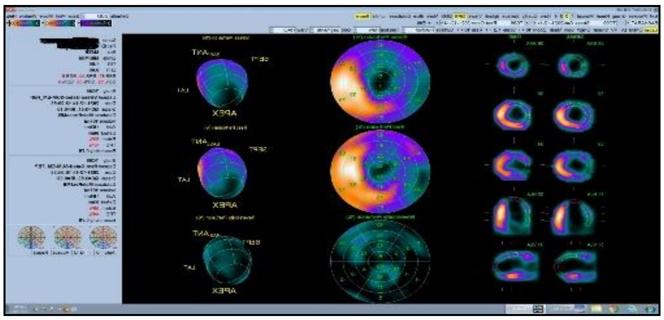

Figure-1: 4DM Nuclear Scan Software Showing Nonviable Segment as dark and Viable Segments as Bright

SSFP was used to access the cardiac function and volumetric analysis. Parametric T1 and T2 pre-contrast maps were used for the quantification of myocardium to analyze infarct and edema respectively. Gadovist 1.0 mmol was the contrast agent used according to patient's weight for the assessment of myocardial viability. Late gadolinium enhancement images were obtained after the 10 minutes of contrast administration. Myocardial viability was assessed on syngo.via and recorded both on 17 and 20 segment model of the heart as shown in (Figure-2A & 2B). The 100% transmural late gadolinium enhance-ment is seen in anterior wall and anteroseptal area that depicts non-viable myocardium in this area.

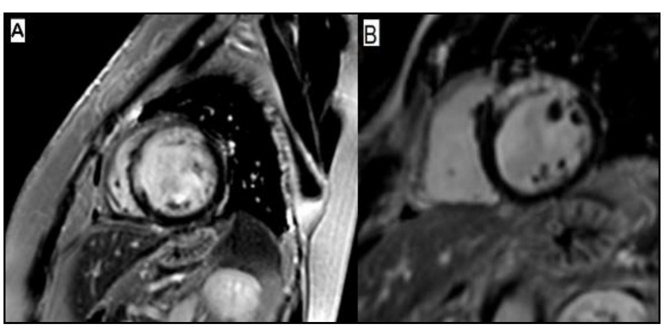

Figure-2A: Upto 75% subendocardial late gadolinium enhancement is seen in anterior wall and septum showing non-viable region with viable rest of the myocardium. 2B: normal healthy myocardium appears hypointense on phase sensitive inversion recovery images after nulling of myocardium

RESULTS

A total of (n=30) patients were selected in this study including 25(83.3%) males and 5(16.7%) females. Table-I depicts baseline clinical characteristics of study population and the number of viable and non-viable myocardial segments in CMR and SPECT scan. In 20 segment model, the mean number of viable segments in SPECT scan and CMR were 16.6±3.18 and 15.47±3.84 respectively, while the non-viable segments were 3.4±3.1 and 5.17±4.6, respectively.

Table-I: Demographics of Study Population

Variables (n=30)		(Mean±SD) F (%)
Age (Years)		52.4±13.7
Height (cm)		168±8.2
Weight (kg)		74±15.8
BMI (kgm^{-2})		26.16±5.58
Gender	Male	25(83.3%)
	Female	5(16.7%)
Comorbids & Procedural Findings		
Risk Factors	HTN	19(63.3%)
	DM	13(43.3%)
Previous MI	AWMI	17(56.6%)
	IWMI	9(30%)
	NIL	4(13.3%)
CT Angiography	SVCAD	4(13.3%)
	DVCAD	6(20%)
	TVCAD	15(50%)
	Minor CAD	5(16.6%)
Number of Viable Segments		
SPECT (20 segments)		16.6±3.18
CMR (20 segments)		15.47±3.84
Number of Non-Viable (Scar) Segments		
SPECT (20 segments)		3.4±3.1
CMR (20 segments)		5.17±4.6

Table-II summarizes the viability of myocardial segments in LAD, LCX and RCA by SPECT scan and CMR. An independent sample t-test was conducted to compare myocardial viability in SPECT scan versus CMR. There was difference between mean values calculated for nuclear scan and CMR in case of LAD and RCA but it was not statistically significant (p-value = 0.624; p-value = 0.475 respectively).

Table-II: Comparison of Myocardial Viability by SPECT Scan and CMR Scan

	Spect (n=30)	CMR (n=30)	*p*-value
LAD	7.4±2.7	7.13±3.27	0.624
LCX	5.6±0.8	4.9±1.76	0.018
RCA	3.5±0.9	3.3±1.03	0.475

The difference between the mean values calculated for SPECT scan and CMR in case of LCx was found to be statistically significant (p-value=0.018).

DISCUSSION

Global incidence of CAD is increasing day by day.[12,13] There are tons of evidence that revascularization can help to return contractile function in presence of viable, ischemic and dysfunction myocardium. Patients with severely reduced LV systolic function but viable myocardium are still candidates of revascularization rather than cardiac transplantation. Revascularization is a cost effective therapy than cardiac transplantation and can significantly improve the quality of life. The significance of revascularization is demonstrated by the surgical treatment for ischemic heart failure (STICH) trial which enlightened the important role of revascularization in patients with chronic CAD. STICH trial compared the CABG and OMT in patients with an EF of equal to or less than thirtyfive percent. The all-cause mortality was 30% versus 41% while cardiovascular mortality was 40.5% versus 49.3% in CABG and OMT alone group, respectively.[14] Schinkel *et al.*[15] revealed that those myocardial segments that had less than five millimeter end-diastolic wall thickness demonstrated considerable possibility of functional recovery after revascularization. It is a clinical challenge to ascertain myocardial viability in patients with previous myocardial infarction. Fortunately, the availability of different non-invasive imaging modalities helps to diagnose and redirect the management of CAD. Among all, PET provides unerring and precise information to detect and diagnose myocardial ischemia followed by CMR.

Recent studies demonstrated that PET and CMR have superior accuracy then SPECT scan in detecting viable myocardium.[1] PET is on the top of list but still CMR demonstrates comparable diagnostic performance.[16-18] Though SPECT scan is the commonly used imaging modality but the advantage of CMR over SPECT scan can be illustrated by lack of ionizing radiation, high resolution, accuracy and lack of stochastic effects.[19] Another advantage of CMR over SPECT scan is the capability to detect even subendocardial perfusion defects. Similarly, CMR can appraise myocardial perfusion in absolute terms. However, despite of great sensitivity and high specificity, ubiquitous use of CMR is restrained by its high cost and availability.[20] Gebel *et al.* illustrated that CMR appeared to be a good imaging modality for identifying viable myocardium for revascularization in patients with severe LV dysfunction as a consequence of ischemic cardiomyopathy.[21] Klein *et al*. showed that CMR gives similar results to PET scan in identifying fibrotic areas of myocardium in patients with severe LV dysfunction and CAD.[22]

Crean *et al.* reported that SPECT scan identified more segments as non-viable when compared with CMR or PET.[23] The strongest consensus among non-invasive perfusion imaging modalities was in anterior wall while the least in inferior wall. In inferior LV segments, SPECT scan overestimates scar due to diaphragmatic attenuation.

Jaarsma *et al.* reported that CMR can be used as an alternative diagnostic modality without hazardous ionizing radiation and provides indistinguishable diagnostic accuracy as PET scan.[24] Similarly, our data suggests that many of the myocardial segments labeled as non-viable by SPECT scan were identified as viable segments by CMR. Thus, CMR is considered the safest and one of the most accurate, reproducible and reliable methods of determining myocardial viability in patients with reduced LV dysfunction & chronic CAD.[25]

LIMITATIONS OF STUDY

There were few limitations to this study. First, it was a single center study. Second, the sample size was very small to make any statistical difference. Third, the gold standard PET scan was not evaluated in comparison to the two modalities due to non-availability. A large, multicenter randomized trial is needed in our population cohort to define outcomes and prognostic value of using these modalities before revascularization in patients with low ejection fraction.

CONCLUSION

In conclusion, the assessment of myocardial viability plays a crucial role for the diagnostic and prognostic work up of patients with CAD who are considered for revascularization. Hibernating and stunned myocardium are reversible contractile dysfunction states that can be corrected with revascularization in severe LV dysfunction and chronic CAD. Many non-invasive imaging modalities are available to differentiate viable and non-viable myocardium. PET scan is superior followed by CMR when compared to SPECT scan. CMR is considered the alternative imaging modality to determine viable myocardium in patients with CAD due its reproducibility, high spatial resolution, high accuracy and lack of exposure to hazardous ionizing radiations whenever PET is not available. We obtained and compare the clinical data using two common non-invasive imaging techniques in a group of patients and have found little variability in results of CMR and SPECT scan. However, SPECT scan should not be used as sole investigator to identify viable myocardium when other more reliable and innocuous modalities exist around.

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Conflict of Interest: None.

Auhtor's Contribution

Following authors have made substantial contributions to the manuscript as under:

IA: Manuscript writing, data collection and concept

AN: Intellectual contribution, concept and final approval

MS: Manuscript writing, concept and editing

NS: Data collection, data analysis and review of article

JA: Intellectual contribution, data collection and manuscript writing

MF: Manuscript writing, data collection and manuscript writing

MA: Study design, drafting the manuscript & critical review

AM: Manuscript writing, formatting and critical review

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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