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Research Article

IMAGE QUALITY OF LATE GADOLINIUM ENHANCEMENT IN CARDIAC MAGNETIC RESONANCE WITH DIFFERENT DOSES OF CONTRAST MATERIAL IN PATIENTS WITH CHRONIC MYOCARDIAL INFARCTION

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Abstract: ***Introduction:*** Late gadolinium enhancement cardiac magnetic resonance imaging (LGE-CMR) is considered the gold standard for assessment of myocardial viability and scar characterization in chronic myocardial infarction (MI). However, the optimal gadolinium-based contrast agent (GBCA) dose required to achieve adequate image quality while minimizing contrast exposure remains uncertain.**Aim:**To evaluate and compare the effect of different gadolinium contrast doses on image quality, signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), and scar visualization in patients with chronic myocardial infarction undergoing LGE-CMR.**Materials and Methods:**This prospective observational study was conducted in the Department of Radiodiagnosis and Imaging at Sher-i-Kashmir Institute of Medical Sciences over a period of 12 months (2021–2022). Thirty patients with chronic myocardial infarction following ST-elevation myocardial infarction (STEMI) were enrolled and divided into three groups based on administered gadodiamide dose: Group A (0.20 mmol/kg), Group B (0.15 mmol/kg), and Group C (0.10 mmol/kg). Cardiac MRI was performed on a 1.5-Tesla scanner using cine and LGE sequences. Image quality, SNR, CNR, ventricular functional parameters, and scar burden were analyzed and compared among groups.**Results:**The majority of patients were male, with anterior wall myocardial infarction being the most common infarct subtype. Left anterior descending artery involvement predominated on coronary angiography and MR evaluation. Subjective image quality, SNR, and CNR1 were significantly lower in the 0.10 mmol/kg group compared with the higher-dose groups ($p < 0.05$). However, no statistically significant differences were observed between the 0.15 mmol/kg and 0.20 mmol/kg groups regarding SNR, CNR, or scar visualization. Left ventricular functional parameters and percentage scar burden showed no significant differences among the three groups.**Conclusion:** Lower gadolinium doses (0.10 mmol/kg) result in reduced image quality and scar conspicuity on LGE-CMR. However, 0.15 mmol/kg gadodiamide provides image quality comparable to 0.20 mmol/kg, without significant compromise in diagnostic performance. Therefore, a gadolinium dose of 0.15 mmol/kg may represent an optimal balance between image quality and contrast administration in chronic myocardial infarction assessment using LGE-CMR.

Keywords: Cardiac MRI Late gadolinium enhancement (LGE)Contrast agents / contrast dose

INTRODUCTION

Ischemic heart disease is a major manifestation of coronary artery disease, with atherosclerosis being the most common underlying cause. Atherosclerosis is a chronic, multifocal immune-inflammatory and fibroproliferative disorder of medium- and large-sized arteries, primarily driven by lipid accumulation within the arterial wall.[1] According to the guidelines of the European Society of Cardiology and the American Heart Association, acute myocardial infarction is defined by a rise and/or fall in cardiac biomarkers in the presence of clinical evidence such as ischemic symptoms, electrocardiographic changes, or imaging evidence of new loss of viable myocardium or regional wall motion abnormalities.[3]

Acute Coronary Syndrome

Acute coronary syndrome (ACS) comprises ST-elevation myocardial infarction (STEMI), non-ST-elevation myocardial infarction (NSTEMI), and unstable angina. A majority of patients presenting with ACS do not demonstrate ST-segment elevation on electrocardiography and are therefore classified as NSTEMI cases.

Utility of Cardiac MRI in Myocardial Infarction

Cardiac magnetic resonance imaging (CMR) has emerged as an important imaging modality in the assessment of acute myocardial infarction. It enables accurate diagnosis, aids in risk stratification and therapeutic planning, and facilitates monitoring of treatment response. CMR allows evaluation of the myocardium at risk using T2-weighted imaging or infarct endocardial surface area (Infarct-ESA). In addition, it can identify microvascular obstruction and intramyocardial hemorrhage, while providing precise assessment of infarct transmurality and the extent of myocardial necrosis.[8]

Late Gadolinium Enhancement Imaging

Late gadolinium enhancement (LGE) imaging is based on differences in contrast wash-in and wash-out kinetics between normal and infarcted or fibrotic myocardium.[9] Gadolinium-based contrast agents rapidly diffuse into the extracellular space but cannot cross intact cell membranes because of their molecular size and chemical properties. As a result, the volume of distribution of gadolinium-DTPA increases in areas of acute myocardial infarction.[11]

Furthermore, delayed wash-out kinetics contribute to the retention of gadolinium within infarcted tissue, producing hyperenhancement on imaging.[12] These kinetic alterations may result from changes in coronary blood flow, capillary permeability, or functional capillary density.[9] After administration of gadolinium contrast, inversion recovery sequences are applied to suppress the signal from normal myocardium, causing infarcted myocardium to appear hyperintense on LGE imaging.

AIMS AND OBJECTIVES

1. To evaluate the image quality of myocardial scar tissue on cardiac magnetic resonance (CMR) imaging using different doses of gadolinium-based contrast agents (GBCAs) in patients with chronic myocardial infarction.
2. To assess the effect of varying gadolinium doses on the visibility of late gadolinium enhancement (LGE) by quantifying signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR).
3. To compare the extent and characteristics of late gadolinium enhancement among patients receiving different contrast doses.

MATERIALS AND METHODS

Study Design and Population

This prospective observational single-center study was conducted in the Department of Radiodiagnosis and Imaging at Sher-i-Kashmir Institute of Medical Sciences over a period of 12 months (2021–2022). The study included 30 consecutive patients referred from the Department of Cardiology with a diagnosis of chronic myocardial infarction following STEMI. Written informed consent was obtained from all participants prior to enrollment.Patients underwent contrast-enhanced cardiac magnetic resonance (CMR) imaging and were categorized into three groups according to the administered gadodiamide dose: Group A received 0.10 mmol/kg, Group B received 0.15 mmol/kg, and Group C received 0.20 mmol/kg.

Inclusion Criteria

1. Adult patients aged ≥18 years.
2. Patients diagnosed with chronic myocardial infarction.

Exclusion Criteria

1. Presence of myocardial edema on CMR suggestive of acute infarction.
2. Patients with non-transmural or very small subendocardial infarcts.
3. Patients with cardiomyopathy or significant arrhythmias.
4. Claustrophobic patients or those with non-compatible metallic implants.
5. Patients with impaired renal function (eGFR <35 mL/min/1.73 m²).
6. Patients unwilling to provide informed consent.

CARDIAC MR PROTOCOL

CMR examinations were performed using a 1.5-Tesla Siemens Healthineers AVANTO MRI scanner equipped with 45 mT/m gradient strength and an 18-channel phased-array surface coil. Patients were positioned supine, and all images were acquired using breath-hold techniques with ECG gating.

The imaging protocol included cine and late gadolinium enhancement (LGE) sequences. Cine true fast imaging with steady-state precession (True FISP) images were acquired in standard short-axis, four-chamber, and two-chamber planes for assessment of ventricular function and wall motion abnormalities.

Following intravenous administration of gadodiamide contrast , dynamic perfusion imaging was performed using FLASH sequences. Delayed enhancement imaging was subsequently obtained using phase-sensitive inversion recovery (PSIR-FLASH) and inversion recovery True FISP sequences. Single-shot TrueFISP imaging was utilized in patients unable to perform adequate breath-holding. Prospective ECG-gated sequences were obtained in patients with arrhythmias.

Imaging Parameters

PSIR-FLASH (Breath-hold)

* TR: 700 ms
* TE: 1.23 ms
* Flip angle: 45°

* Inversion time: 300 ms
* Slice thickness: 8 mm
* Bandwidth: 78

IR-True FISP (Non-breath-hold)

* TR: 580 ms
* TE: 1.22 ms
* Flip angle: 50°
* Inversion time: 330 ms
* Slice thickness: 8 mm

LGE imaging was performed using a 2D segmented inversion recovery fast gradient-echo sequence covering the entire left ventricle. The inversion time was adjusted between 260 and 330 ms to null the signal from normal myocardium. Image acquisition was synchronized to mid-diastole to minimize motion artifacts. Delayed enhancement scans were obtained at time intervals adjusted according to the administered contrast dose, as recommended in the literature.

IMAGE ANALYSIS

Image analysis was performed using Argus Function software (Siemens Healthineers). Epicardial and endocardial contours of the left ventricle were manually traced on cine short-axis images at end-diastole and end-systole. The software automatically calculated indexed end-diastolic volume, end-systolic volume, myocardial mass, stroke volume, and ejection fraction.
Scar tissue was identified on inversion recovery sequences as areas demonstrating late gadolinium enhancement. Manual contouring of scarred myocardium was performed, and total scar burden was quantified as the percentage of LGE relative to total myocardial mass.
Regions of interest (ROIs) were placed within:

* Scarred myocardium
* Remote healthy myocardium
* Ventricular blood pool
* Background air

RESULTS

The present study was undertaken in the Department of Radiodiagnosis and Imaging, Sher-i-Kashmir Institute of Medical Sciences, Souraon 30 referred patients with Clinical diagnosis of Myocardial Infarction. gender ratio was found to be almost similar in all the groups. In group A, the males were 80% and 20% were females. In group Band C, there were 70% males and 30% females. Mean age ± SD of age (years) in group A was 64.8 ± 9.98, in group B it was 60.1 ± 12.91 and in group C the mean age ± SD was found to be 54.4
Table 1

Distribution of Study Participants according to ECG Findings

		ECG FINDINGS			
	Type of MI	ST ELEVATION IN LEAD V1 to V4	ST ELEVATION IN LEAD II, III and aVF	ST DEPRESSION IN LEADS V1-V4	LVHWITH STRAIN PATTERN
Group A	AWMI	3(30.0%)	0(0.0%)	0(0.0%)	3(30.0%)
	PWMI	0(0.0%)	0(0.0%)	2(20.0%)	0(0.0%)
	IWMI	0(0.0%)	2(20.0%)	0(0.0%)	0(0.0%)
Group B	AWMI	2(20.0%)	0(0.0%)	0(0.0%)	2(20.0%)
	PWMI	0(0.0%)	0(0.0%)	3(30.0%)	0(0.0%)
	IWMI	0(0.0%)	2(20.0%)	0(0.0%)	1(10.0%)
Group C	AWMI	4(40.0%)	0(0.0%)	0(0.0%)	3(30.0%)
	PWMI	0(0.0%)	0(0.0%)	1(10.0%)	0(0.0%)
	IWMI	0(0.0%)	1(10.0%)	0(0.0%)	1(10.0%)

As shown in Table 6, In group A, 30% of patients had AWMI with ST elevation in lead V1 to V4 on ECG and 30% had AWMI with left ventricular hypertrophy (LVH) with strain pattern on ECG. 20% of patients had PWMI with ST depression in leads V1-V4while the remaining 20% of patients in group A had IWMI with ST elevation in II, III, and a VF.

In group B, 20% of patients had AWMI with ECG showing S Televation in lead V1 to V4 and 20% of patients had AWMI with ECG finding as LVH with strain pattern. 30% of patientswithPWMIhadSTdepressioninLeadsV1-V4.20%ofpatientswithIWMIgroup B had ST elevation in II, III, and a VF and 10% of patients with IWMI had ECG finding as LVH with strain pattern.

In group C, in patients with AWMI, 40% had ST elevation in lead V1 to V4 and 30% had LVH with strain pattern. 10% of patients with PWMI had ST depression in Leads V1-V4. In patients with IWMI,10%had S Televation in leads

II,III,andaVFand10%hadLVH with strain pattern on ECG. concentric LVH. 20% of patients with PWMI had posterior wall hypokinesia while the remaining 20% of patients with IWMI had inferior wall hypokinesia.

In group C, among patients with AWMI, 70% had anterior wall hypokinesia and 30% had concentric LVH. 10% of patients with PWMI had posterior wall hypokinesia while the remaining 20% of patients with IWMI had hypokinesia of the inferior wall.

Table 2:

Distribution of study participants according to PCI.

PCI	Group A	Group B	Group C
PCITOLAD	6(60.0%)	4(40.0%)	7(70.0%)
PCITORCA	3(30.0%)	4(40.0%)	5(50.0%)
PCITOLCX	3(30.0%)	4(40.0%)	4(40.0%)
PCITOOM	5(50.0%)	3(30.0%)	4(40.0%)

As shown in Table 8, In group A, 60% of people underwent PCI to LAD, 30% to RCA, 30% to LCX, and 50% underwent PCI to OM. In group B, 40% of participants each underwent PCI to LAD, PCI to RCA, and PCI to LCX, and 30% underwent PCI to OM. In group C, the majority of participants (70%) underwent PCI to LAD followed by PCI to RCA (50%), and then to LCX and OM (40% each).

Table 3

Distribution of CAG among three groups

CAG	Group A	Group B	Group C
LAD disease [80-90%]	6(60.0%)	4(40.0%)	7(70.0%)
LAD disease [70-75%]	1(10.0%)	2(20.0%)	2(20.0%)
LAD disease [60-70%]	3(30.0%)	5(50.0%)	1(10.0%)
RCA disease [75-80%]	3(30.0%)	3(30.0%)	2(20.0%)
RCA disease [70-75%]	4(40.0%)	3(30.0%)	4(40.0%)
RCA disease [60-65%]	2(20.0%)	0(0.0%)	4(40.0%)
LCX disease [75-80%]	2(20.0%)	3(30.0%)	1(10.0%)
LCX disease [70-75%]	6(60.0%)	8(80.0%)	3(30.0%)
LCX disease [65-70%]	3(30.0%)	2(20.0%)	6(60.0%)

Table 4

Left ventricular function and volume, and scar data from the three study sub groups

	Group A (0.20 mmol/kg)	Group B (0.15 mmol/kg)	Group C (0.10 mmol/kg)	F-value	p-value
LV EDVI (ml/m^2)	93.20±9.72	95.8± 11.22	93.5± 14.11	0.145	0.866^{NS}
LV ESVI (ml/m^2)	53.8±7.89	48.5±8.15	50.8±12.91	0.72	0.497^{NS}
LVSV(ml)	49.20±4.42	47.61±4.40	44.7±4.79	2.53	0.098^{NS}
LVEF(%)	51±2.29	49.88±3.44	48.23±4.50	1.56	0.228^{NS}

LVMI (g/m^2)	98.3±8.38	109.8±32.39	100.2±8.48	0.96	0.397^{NS}
LGE(%)	32.49±9.77	34.4±5.48	31.74±3.41	0.41	0.666^{NS}

NS=Not significance

Table5:

Image quality and noise ratio differences among the three groups according to gadolinium enhancement

	Group A (0.20 mmol/kg)	Group B (0.15 mmol/kg)	Group C (0.10 mmol/kg)	F-value	p-value
SIQ	2.70±0.48	2.3±0.82	1.80±0.79	3.98	0.031*
SNR	84.06±15.33	81.41±20.07	55.16±6.68	11.22	<0.0001*
CNR1	114.3±18.45	107.57±36.31	74.66±10.86	7.6	0.002*
CNR2	42.9±14.99	39.41±15.99	28.45±5.62	3.3	0.051^{NS}

**** = Significant at 0.01 level of significance***
NS=Not significant

Table6

Post hoc analysis using least significant difference (LSD) for pair wise comparison.

Dependent Variable	(I) CONTRAS T	(J) CONTRAS T	Mean Difference (I-J)	p-value	95% Confidence Interval	
					Lower Bound	Upper Bound
Subjective image quality (SIQ))	0.10 mmol/kg	0.15 mmol/kg	-0.50	0.388 NS	-1.32	0.32
	0.15 mmol/kg	0.20 mmol/kg	-0.40	0.665 NS	-1.22	0.41
	0.20 mmol/kg	0.10 mmol/kg	0.90	0.027 *	0.08	1.72
Signal to noise ratio (SNR)	0.10 mmol/kg	0.15 mmol/kg	-26.25	0.001 *	-40.09	-12.41
	0.15 mmol/kg	0.20 mmol/kg	-2.65	0.697 NS	-16.49	11.19
	0.20 mmol/kg	0.10 mmol/kg	28.90	0.001 *	15.06	42.74
Contrast to noise ratio (CNR1)	0.10 mmol/kg	0.15 mmol/kg	-32.91	0.005 *	-55.24	-10.58
	0.15 mmol/kg	0.20 mmol/kg	-6.73	0.541 NS	-29.06	15.60
	0.20 mmol/kg	0.10 mmol/kg	39.64	0.001 *	17,.31	61.97

****=Significant at 0.01 level of significance***

Table7

Distribution of study participants according to the type of MR vessel.

MR Vessel	Group A	Group B	Group C
LAD	6(60.0%	4(40.0%)	7(70.0%)
RCA	3(30.0%)	4(40.0%)	5(50.0%)

LCA	1(10.0%)	1(10.0%)	3(30.0%)
LCX	5(50.0%)	7(70.0%)	6(60.0%)

IMAGES

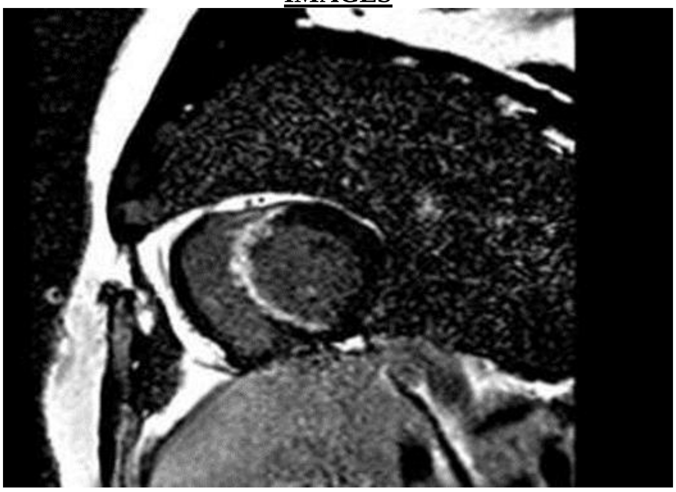
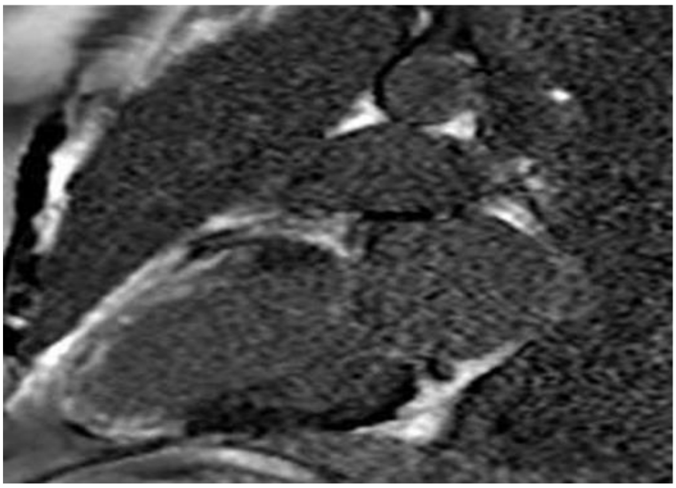


Figure. 4[a]
Inversion recovery sequence for late gadolinium enhancement performed using 0.20mmol/kg of gadodiamideina male patient of 49 years of age showed in farct size



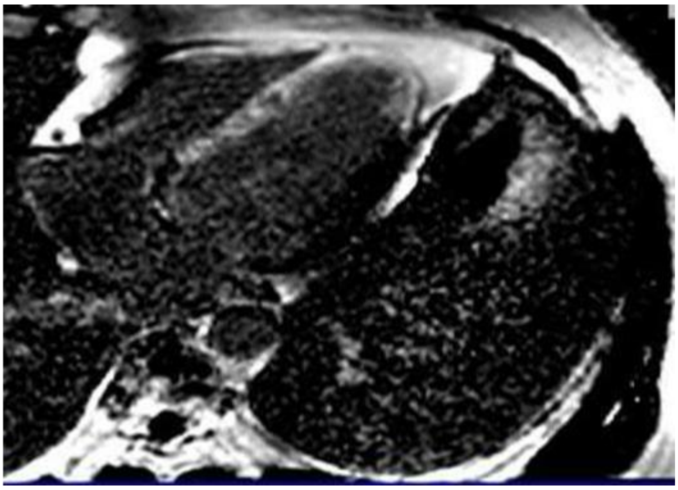


Figure. 4[b] **Figure. 4[c]**
2 chamber of 0.20mmol/kg contrast **4 chamber of 0.20mmol/kg contrast**

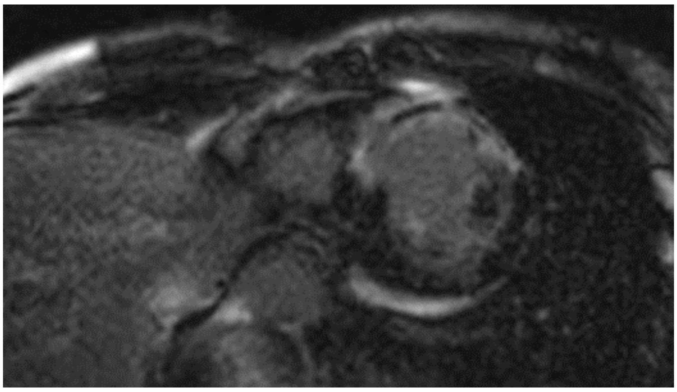


Figure.5[a]
Inversion recovery sequence for late gadolinium enhancement performed using 0.15 mmol/kg of gadodiamideina male patient of 54 year so fage showed in farct size

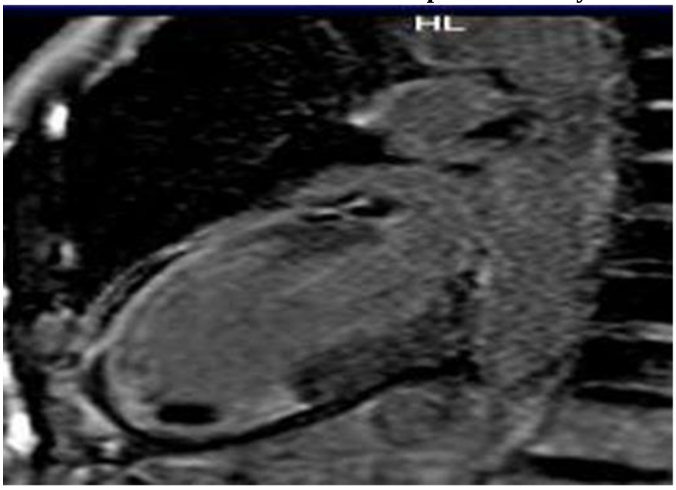
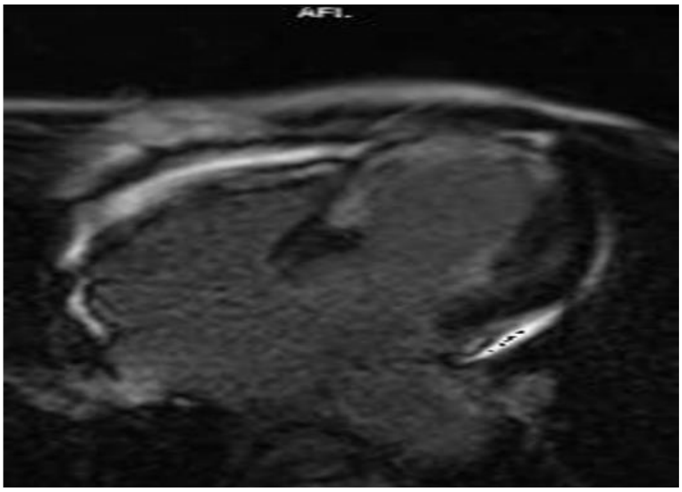



Figure.5[b] **Figure.5[c]**
2 chamber of 0.15mmol/kg contrast **4 chamber of 0.15 mmol/ kg contrast**

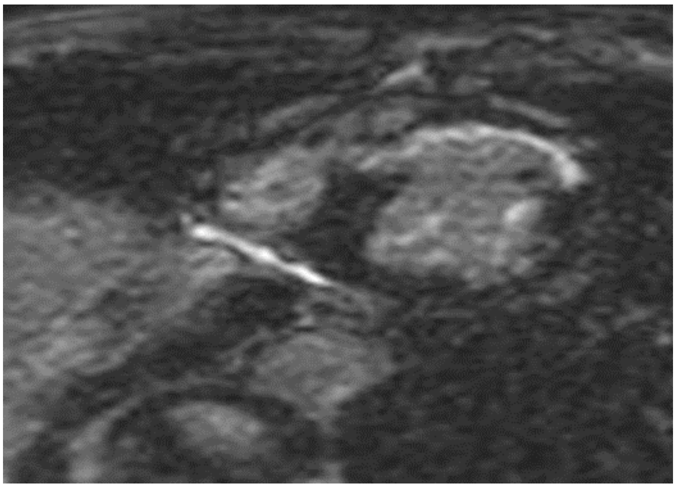


Figure.6[a]
Inversion recovery sequences for late gadolinium enhancement perform edusing 0.10mmol/kg of gadolinium in a male patient of 78 years of age showed infarct size.

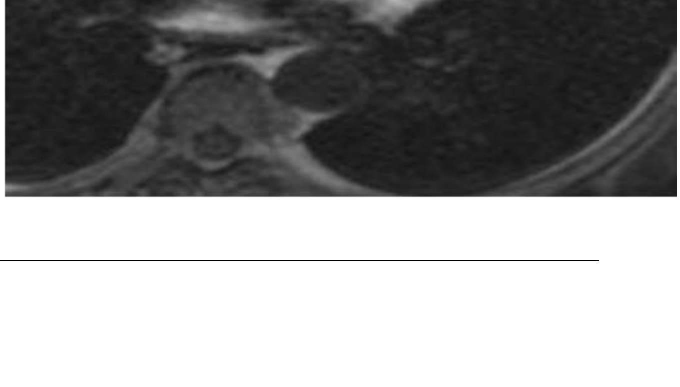



Figure.6[b]
2 chamber of 0.10mmol/kg contrast

Figure.6[c]
4 chamber of 0.10mmol/kg contrast

DISCUSSION

Acute myocardial infarction (MI) commonly results from disruption of coronary artery blood flow secondary to plaque rupture or erosion, leading to prolonged myocardial ischemia and irreversible myocyte injury. Less common causes include coronary vasospasm, vasculitis, embolism, and coronary artery dissection. Assessment of myocardial viability is essential for predicting recovery of contractile function following revascularization, and cardiac magnetic resonance imaging (CMR) with gadolinium contrast remains the gold standard for viability assessment.

Late gadolinium enhancement (LGE) imaging is a highly sensitive and specific CMR technique for assessing myocardial infarction and scar burden. Gadolinium-based contrast agents shorten T1 relaxation time and accumulate within areas of increased extracellular volume caused by myocyte necrosis and fibrosis, resulting in hyperenhancement on T1-weighted inversion recovery images acquired 10–20 minutes after contrast administration. In the present study, different gadolinium doses were evaluated to determine their effects on scar enhancement, signal-to-noise ratio (SNR), and contrast-to-noise ratio (CNR).

The majority of patients in our study were male (73.3%), which is comparable to studies by Zhang et al.[17] and Becker et al.[18], who reported male predominance of 80.6% and 76.5%, respectively. The mean age of patients was above 50 years in all groups, consistent with previous studies evaluating chronic myocardial infarction.[17,19]

A higher proportion of patients belonged to urban areas compared to rural areas (56.67% vs. 43.33%), similar to findings reported by Abrams et al.[20]. Most patients were overweight (56.67%), followed by obese individuals (23.33%), which corresponds with the observations of Oreopoulos et al.[21], supporting the association between increased body mass index and coronary artery disease.

Anterior wall myocardial infarction (AWMI) was the most common infarct type in our study (57%), followed by inferior wall MI (23%) and posterior wall MI (20%). Similar findings were reported by Pandey et al.[22], although Wang et al.[23] observed a predominance of inferior wall MI. Electrocardiographic findings in our study correlated well with infarct location, with ST-segment elevation in leads V1–V4 predominantly associated with AWMI and ST elevation in leads II, III, and aVF associated with inferior wall MI.

Regional wall motion abnormalities on echocardiography showed good agreement with infarct localization. Most patients with anterior wall MI demonstrated anterior wall hypokinesia, while inferior and posterior wall infarctions were associated with corresponding regional hypokinesia. These findings were consistent with observations reported by Pandey et al.[22]

Percutaneous coronary intervention (PCI) was performed in all patients. The left anterior descending artery (LAD) was the most frequently treated vessel, followed by the right coronary artery (RCA) and left circumflex artery (LCx), similar to findings reported by Omer et al.[24] Coronary angiography also demonstrated LAD as the most commonly involved artery with significant stenosis (>70%), followed by RCA and LCx disease. Comparable patterns of coronary artery involvement have been described in earlier angiographic and autopsy studies.[25-29]

Assessment of left ventricular volumetric and functional parameters using CMR revealed no statistically significant differences among the study groups. Parameters including LV end-diastolic volume index, LV end-systolic volume index, stroke volume, ejection fraction, myocardial mass index, and percentage scar burden were similar across all contrast-dose groups. These findings are in agreement with Monti et al.[30], who also demonstrated no significant influence of gadolinium dose on left ventricular functional or scar burden measurements.

Subjective image quality was highest in patients receiving 0.20 mmol/kg gadolinium contrast; however, differences between the 0.15 mmol/kg and 0.20 mmol/kg groups were minimal. Quantitative analysis demonstrated lower SNR and CNR values in the 0.10 mmol/kg group, indicating reduced scar conspicuity and greater image noise at lower contrast doses. In contrast, no significant differences in SNR or CNR were observed between the 0.15 mmol/kg and 0.20 mmol/kg groups, suggesting comparable image quality between these two doses.

These findings closely parallel those reported by Monti et al.[30], who also observed significantly lower SNR and CNR values with 0.10 mmol/kg contrast administration, while 0.15 mmol/kg and 0.20 mmol/kg doses produced comparable image quality. Variations between our quantitative measurements and those reported by De Cobelli et al.[31] and Durmus et al.[32] may be related to differences in imaging protocols and methods used for SNR calculation.

Cardiac MRI demonstrated LAD territory infarction as the most common pattern, with LAD identified as the culprit vessel in 56.67% of patients. RCA involvement was seen in 40% of cases, whereas LCx involvement was relatively uncommon. Similar findings were reported by Van Kranenburg et al.[33], further supporting the predominance of LAD involvement in chronic myocardial infarction.

Overall, our findings suggest that although lower gadolinium doses reduce image quality and scar conspicuity, there is no significant advantage of using 0.20 mmol/kg over 0.15 mmol/kg contrast dose for assessment of chronic myocardial infarction using LGE-CMR. Therefore, a contrast dose of 0.15 mmol/kg may provide an optimal balance between image quality and contrast administration.

Conclusion

The present study concluded that laparoscopic cholecystectomy is a safe, effective, and reliable surgical procedure for the management of symptomatic gallstone disease. The majority of patients were middle-aged females presenting with abdominal pain and dyspeptic symptoms. Ultrasonography findings such as multiple gallstones and gallbladder wall thickening were commonly observed and were useful in identifying potentially difficult cases. Most surgeries were completed successfully laparoscopically with a low conversion rate to open surgery. Postoperative complications were minimal, hospital stay was short, and the majority of patients achieved good postoperative recovery. The findings of the study support the role of laparoscopic cholecystectomy as the preferred treatment modality for gallstone disease due to its favorable surgical and postoperative outcomes.

Limitations

The study was conducted at a single tertiary care centre, which may limit generalizability of the findings to other healthcare settings. The sample size was relatively limited, and long-term postoperative follow-up was not included in the study. Advanced assessment of quality of life and long-term recurrence of biliary symptoms were not evaluated. In addition, variations in surgeon experience and operative expertise could have influenced intraoperative and postoperative outcomes.

Recommendations

Preoperative clinical and ultrasonographic assessment should be performed carefully to identify patients at risk of difficult laparoscopic cholecystectomy. Early surgical intervention may help reduce complications associated with chronic inflammation and adhesions. Adequate surgical training and adherence to standard laparoscopic techniques are essential to minimize bile duct injuries and conversion rates. Larger multicentric studies with long-term follow-up are recommended to further evaluate postoperative quality of life, recurrence of symptoms, and predictors of surgical outcomes following laparoscopic cholecystectomy.

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