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MRI assessment of left ventricular volumetrics and ejection fractions in patients with chronic ischemic heart disease in comparison with 2D echocardiography

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Abstract

Background: Ischemic heart disease (IHD) is highly prevalent in developed countries and is the leading cause of death. Diagnostic imaging plays an important role in the proper assessment and management of ischemic heart disease. The new criteria incorporating imaging evidence of ischemic heart disease involve not only established modalities such as echocardiography and radionuclide imaging, but also the newer modalities, cardiovascular magnetic resonance (CMR) and cardiac computed tomography especially in presence of pitfalls and limitations in diagnosis by established modalities.

Aim: To assess left ventricular volumes; end diastolic volume (EDV), end systolic volume (ESV), stroke volume (SV), ejection fraction (EF) and wall motion abnormalities by MRI in patients with chronic ischemic heart disease in comparison with 2D echocardiography.

Patients and Methods: This prospective study include examination of 50 adult patients known to have chronic ischemic heart disease with or without suspected progression of the disease came for follow up by MRI and 2D echocardiography in Cairo university and Aswan heart center (MYF) radiology and cardiology departments. MRI was done by using 1.5T machine, using SENSE (sensitivity encoding) cardiac coil (6 element phased-array coil, receive only), functional cine images, first pass perfusion images and delayed enhancement images were acquired. Echocardiography was done transthoracic (TTE) by using a 2D ultrasound machine. The left ventricle volumes and ejection fractions obtained by MRI were compared to those obtained by echocardiography and correlated with standard tables of left ventricle volumetrics. Wall motion abnormalities were assessed visually by both modalities.

Results: By comparison of the diagnostic performance of MRI versus 2D echo in estimation of left ventricle volumes and ejection fraction there was agreement and strong correlation value (0.97) between both modalities however, we found that the left ventricle volumes were of lower values by echocardiography relative to MRI with statistically significant difference with P value (0.004) and we found that the EFs detected by echocardiography were of higher values relative to MRI with statistically significant difference with P value (<0.001). As regard wall motion abnormalities, both CMR and 2D echo detected the hypokinetic and akinetic left ventricle segments with no statisticaly significant difference.

Conclusion: Cardiac MRI can detect the impairment in left ventricle function in patients with ischemic heart disease and is an accurate tool for assessment of left ventricle volumes and ejection fraction and can be considered as a standard reference for these issues.

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Keywords: **left ventricular volumetrics, Cardiac magnetic resonance imaging, echocardiography, ischemic heart disease.**

INTRODUCTION

Ischemic heart disease (IHD) is highly prevalent in developed countries and is the leading cause of death (**Go et al, 2014**). Diagnostic imaging plays an important role in the proper assessment and management of ischemic heart

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disease. The new criteria incorporating imaging evidence of IHD involve not only established modalities such as echocardiography and radionuclide imaging, but also the newer modalities, cardiovascular magnetic resonance (CMR) and cardiac computed tomography especially in presence of pitfalls and limitations in diagnosis by established modalities **(Roman L et al 2016)**. As regard echocardiography, technical development is still on-going, and various new ultrasound techniques have been established in the field of echocardiography in the last several years, including tissue Doppler imaging (TDI), contrast echocardiography, three-dimensional echocardiography (3DE), and speckle tracking echocardiography (i.e., strain/strain rate-echocardiography) however, there are pitfalls and limitations in diagnosis of myocardial ischemia by echocardiography e.g. *The low reproducibility. *The “low volume” of SE examinations by a single operator in clinical practice. *At the frame rates of 3DE and SE, spatial and temporal resolutions, and the acquisition of a sufficient number of volumes per heart cycle become a problem. *The acoustic window for echocardiography may represent a problem in some cases especially when a safe answer for decision making regarding interventional procedures is needed. *Echocardiographic perfusion analysis is not sufficiently reliable and has failed to be implemented in daily routines. In these cases, an additional imaging technology, such as CMR or single-photon emission computed tomography (SPECT), is needed **(Roman L et al 2016).**

Advances in rapid magnetic resonance imaging technology and its application to cardiac imaging have shown that MR imaging has tremendous potential for evaluation of cardiac disease (**Reeder et al 2001, Kramer 2007, Lin et al 2008).** During the past decade, CMR has evolved from a research tool performed in a few selected centers to a clinical diagnostic tool that is recognized as the gold standard in the quantitative assessment of left ventricular function. It is now established as a comprehensive clinical tool offering cardiologists different information on cardiac function, anatomy and tissue characteristics. It accurately assesses ischemia, inflammation and viability ***(Bettencourt N et al 2009)*.** Cardiac MR imaging (CMR) is the reference standard for the assessment of global left ventricular function **(Collins J.D, 2015).** Systolic function is determined through quantitation of the EDV, ESV, SV and LV ejection fraction (EF) **(Collins J.D, 2015).** The accuracy of the assessment of global LV systolic function at CMR would be incomplete without considering agreement with other modalities like 2D transthoracic echocardiography (TTE).

PATIENTS AND MRTHODS

Patients:

50 patients with known chronic ischemic heart disease came with or without suspected progression of the disease were enrolled in the study between January 2010 and August 2015. The age of the patients ranged between 40 and 80 years old with mean age 60 years. There were a total number of 40 males and 10 females.

The major inclusion criterion was presence of ischemic heart disease. Patients enrolled in this study had to fulfill the following criteria; sinus heart rhythm, able to hold breath for accepted time (10-20 seconds) and normal serum creatinine. **Exclusion criteria** were;

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hemodynamic instability, atrial fibrillation, contra-indications for MR imaging; claustrophobia, patients with pacemaker or metal implants, contraindication for contrast material including known allergy and renal insufficiency (serum creatinine more than 1.4 mg\dl).

Methods:

All patients underwent cardiac MRI and 2D echocardiography.

I- CMR:

No special instructions are required prior to the examination. Medications are not to be discontinued. First, a short medical history was taken. Patients were then screened for contraindication to MR imaging. All undergarments containing nylon or metal were removed. The former may cause artifacts because of static electricity and the latter can cause image degradation. Before the examination; the heart rate and rhythm were evaluated. To evaluate patients ability of breath-withholding for relatively long time; they were asked to perform a deep inspiration and to hold their breath without pushing (i.e., Valsalva maneuver).

30 patients underwent the MRI examination by A Philips Achiva, Netherland (1.5 Tesla) superconducting magnet in radiology department -Cairo university. 20 patients underwent the MRI examination by Siemens 1.5 T. in Aswan heart center (at MYF). The SENSE (sensitivity encoding) cardiac coil (6 element phased-array coil, receive only) was used.

Imaging protocol:

All patients received 18-gauge intravenous line to allow administration of the contrast agent. The patients underwent a standard MR examination that included the following steps:

1.Scout images were acquired in orthogonal orientations for planning of the final long-axis and short-axis views.

2.Functional cine images: were acquired using electrocardiographic gated, breath hold balanced turbo field echo (b-TFE) sequence in short axis view. Eight to eleven short-axis views 1 cm apart, were obtained during repeated breath-holds, starting from the mitral valve insertion and covering the entire left ventricle with the following parameters:

TR/TE: 4.4/2.5 FOV: 300
Phases: 25 NSA: 1
Matrix: 128x128 Bandwidth: 125 kHz
Flip angle: 15° Scan Time: 0.07-0.12 sec.
Slice thickness: 8mm Slice number: 8-11

3. First pass rest perfusion imaging

It is performed by intravenous bolus injection of 0.025 mmol/kg of gadopentetate dimeglumine (Magnevist) at an injection rate of 5 mL/sec followed by a flush of 20 mL of saline solution at the same rate. Scanning was started about 10 seconds after the starting of contrast injection and continues for about 1 minute. Breath-hold first-pass perfusion MR imaging was performed by using a hybrid gradient echo-planar imaging pulse sequence. This pulse sequence yields three sections (at basal, mid-cavitary and apical levels) in the short-axis view covering the entire left ventricle every other heart beat with the following parameters:

TR/TE: 2.9/1.46 FOV: 350
Phases: 25 NSA: 1
Matrix: 128 x 128 Bandwidth: 125 kHz
Flip angle: 20° Scan Time: 1 sec.
Slice thickness: 8mm Slice number: 3

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4. An additional bolus of 0.1-0.2 mmol/kg gadopentetate dimeglumine immediately after ending the rest perfusion scan.

5. Additional functional cine images were acquired using similar parameters to the previously described cine sequences. Four to six long-axis views (Two or Four chamber views), 1 cm apart, were obtained during repeated breath-holds.

6. Standard delayed gadolinium enhancement imaging was performed by using Segmental inversion recovery balanced turbo field echo (IR-b-TFE), starting 10–20 min after the last injected intravenous bolus of contrast). Contrast-enhanced images were acquired in the same orientation as the cine images (short axis plane) and at least one of the long axis plane with the following parameters:

TR/TE: 3.8/1.86 FOV: 300
TI: 260-350 NSA: 1
Matrix, 128x128 Bandwidth: 125 kHz
Flip angle: 15° Scan Time: 9-15 sec.
Slice thickness: 8mm Slice number: 8-11

The mean time of the MR imaging examination was 40 minutes. All patients underwent the complete MR imaging examination without severe complications.

MR Image analysis:

Images (DICOM) were transferred to a workstation equipped with a dedicated cardiac software package for further post-processing analysis:

1. Global LV Function: Global functional parameters were derived from cine MRI, with the aid of commercially available software. The endocardial border of the left ventricle was traced manually from the short axis images during systole and diastole. LV end-diastolic volume (EDV) and end-systolic volume (ESV) were calculated on the basis of Simpson's rule. Subsequently, stroke volume (SV) and ejection fraction (EF) was calculated using EDV and ESV values. The results are compared to those derived from the 2D echocardiography.
2. For regional wall motion analysis: cine MRI was evaluated and compared to those obtained from the 2D echocardiography. Wall motion abnormality was classified into:

§ Mild-to-moderate hypokinesia.
§ Severe hypokinesia.
§ Akinesia or dyskinesia.

II-Echocardiography:

All patients were scheduled for transthoracic echocardiogram "TTE" within 15 days of the MRI examination. TTE was performed by a 2D ultrasound machine. The exam was performed with the subject supine in the left lateral position. The dimensions of the left ventricle and EF were estimated. Wall motion abnormality was classified into:

§ Mild-to-moderate hypokinesia.
§ Severe hypokinesia.
§ Akinesia or dyskinesia.

Statistical analysis:

Findings of the cardiac MRI were compared to those of the corresponding 2D echocardiography as regard left ventricle volumetrics, ejection fractions and wall motion abnormalities.

Data were analyzed using IBM SPSS Statistics for Windows version 22.0

Quantitative data was expressed as means ± standard deviation, median and range. Qualitative data was expressed as number and percentage. The data were tested for normality using Shapiro -Wilk test. Paired T test was used for normally distributed data. McNemar's test,

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McNemar-Bowker test and Chi-Square test were used for comparison between different diagnostic methods. A 5% level was chosen as a level of significance in all statistical tests used in the study.

RESULTS

The study group consisted of 50 patients and the results were analyzed as follows:

Patients' characteristics:

- **Patient sex:**

Fifty patients were included in this study, 40 males (80%) and 10 females (20%) **(Chart 1).**

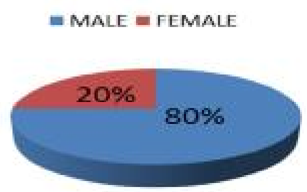

Chart 1. Sex distribution in the study

-Patient age:

The patient's age was ranged between 40 and 80 years with mean age of 60 years.

The study findings:

50 patients were examined by MRI and 2D echocardiography, the left ventricle volumes and EFs were estimated by MRI and 2D echo and we got the following:

By comparison of the diagnostic performance of MRI versus 2D echo in estimation of left ventricle volumes we found that the left ventricle volumes were of lower values by echocardiography relative to MRI with statistically significant difference with P value (0.004) where the echo detected left ventricle dilatation in 26 patients form 50 patients (52%) and normal sized left ventricle in 24 patients (48%) while MRI detected left ventricle dilatation in 35 patients from 50 patients (70%) and normal sized left ventricle in 15 patients (30%)…**table (1)**

Left ventricle size	Investigation		P-value
	MRI	Echocardiography	
Dilated	35 (70%)	26 (52%)	0.004*
Normal	15 (30%)	24 (48%)	
Total	50	50	

Table (1): Diagnostic Performance of Cardiac MRI versus 2D echocardiography in estimation of left ventricular size

P- value was calculated by McNemar's Test

*** Statistically significant**

By comparison of the diagnostic performance of MRI versus the 2D echo in estimation of left ventricle EFs we found that the EFs detected by echocardiography were of higher values relative to MRI with statistically significant difference with P value (<0.001) where the EFs detected by MRI were: mean±SD=42±15.25 % with median (range)=40(12-76) % while the EFs detected by echo were: mean±SD=46.22±14.32 % with median (range)=47(20-77) %…**table (2).**

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Ejection fractions (EFs) (%)	Investigation		P-value
	MRI	Echocardio graphy	
Mean± S.D. Median (Range)	42 ± 15.25 40 (12 - 76)	46.22 ± 14.32 47 (20 - 77)	<0.001*

Table (2): Diagnostic Performance of Cardiac MRI versus 2D echocardiography in estimation of EFs. P- value was calculated by Paired T Test. * Statistically significant

<u>As regard wall motion abnormalities:</u>

Both CMR and 2D echo detect mild to moderate hypokinesia in 25 patients, severe hypokinesia in 15 patients and akinesia in 10 patients with no statisticaly significant difference.

ILLUSTRATED CASE

80 years old man known to be ischemic for 9 years, extensive anterior MI with stent insertion. Now he is presented with ventricular tachycardia and sent to MRI for scar assessment.

- **Echocardiographic Findings:**

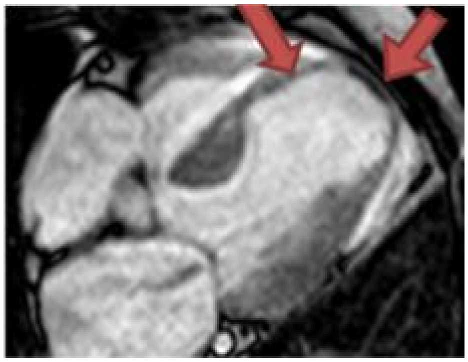
*Normal left ventricular dimensions.
*EF. =46%
*Segmental wall motion abnormalities in the form of:
- Dyskinetic apex and akinetic adjoining apical segments.
- Akinetic mid-segments of anterior wall and anterior septum.

- **Cardiac MRI Findings:**

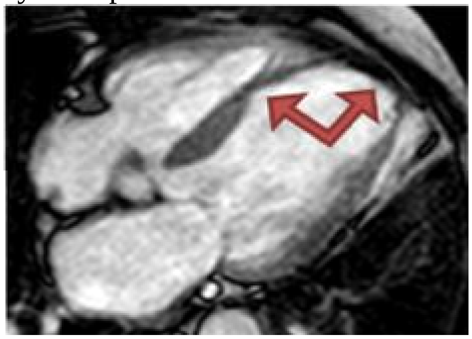
A. <u>Cine Sequences</u> ***(Figures 1 and 2)***:

§ Globally, the left ventricle shows mild dilatation.

§ Thinning (less than 6 mm thickness) and akinesia of the anterior, anteroseptal and septal segments of the left ventricular wall at the mid-cavitary and apical levels.



(A)



(B)

Figure 1. MR findings in case 1. ECG gated TFE cine sequence in four chamber plane of the heart in systole (A) and in diastole (B). Arrows refer to the thinning of the myocardium (less than 6 mm) at the septal wall and apex of left ventricle.

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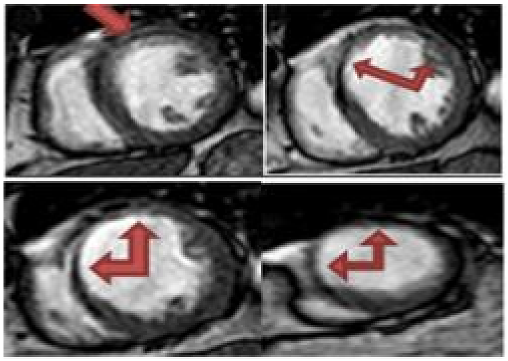
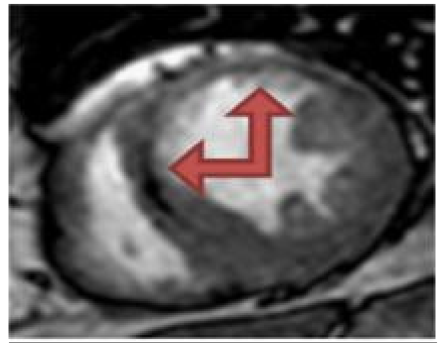


(A)



(B)

Figure 2. MR findings in case 1. ECG gated TFE cine sequence in short axis plane of the heart in diastole (A). and in systole (B). Arrows refer to the thinning of the myocardium at the anterior, antero-septal and septal segments at the mid-cavitary and apical levels.

Left ventricular function is as follows:

- Left ventricular ejection fraction: 31 %
- Left ventricular end diastolic volume:182 mls
- Left ventricular end systolic volume:126 mls
- Left ventricular stroke volume: 56 mls

B. Tissue characterization:

In the 3D IR sequence, there is transmural (75-100 %) enhancing scar at the left ventricular wall involving anterior, anteroseptal and septal segments at the mid-cavitary and apical levels and extends to involve the cardiac apex circumferentially ***(Figure 3).***

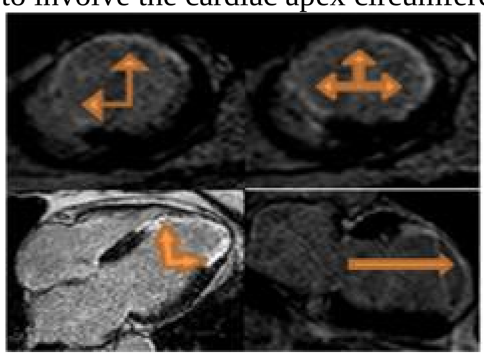


Figure 3. MRI findings in case 1.: Post Gd DTPA 3D IR sequence in short axis plane **(A-B images)**, in four chamber plane **(C image),** and 2CH plane **(D image).** Arrows refer to the transmural enhancing scar involving the anterior, anteroseptal, septal and apex segments of the left ventricle.

DISCUSSION

Within the past decade, cardiac MR imaging has emerged as the standard of reference for the assessment of functional and structural myocardial abnormalities in different cardiac diseases ***(Sakuma H et al, 2005; Ruth PL et al, 2007).***

Imaging of IHD is not limited to the mere visualization of coronary arteries for detection of stenotic or occluded coronary arteries. Accurate and early identification of viable myocardium is also important, especially for treatment modalities and prognosis.

Our study was performed for 50 patients known to have IHD with or without suspected progression of the disease. They underwent the CMR examination with no complications.

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In our study, there was agreement between CMRI and 2D echocardiography with strong correlation value (0.97) in the assessment of left ventricular volumes and EFs however, the left ventricular volumes were of lower values by the 2D echocardiography relative to MRI with P value = .004* (statistically significant) and the EFs were of higher values by the 2D echo relative to MRI with P value = < .001* (statistically significant).

In line with our study, a study by **Bellenger NG et al, 2000,** investigated 50 patients with chronic IHD and systolic heart failure, demonstrating the best agreement between 2D echocardiography and CMR with correlation values ranging from 0.41 to 0.9 and the standard deviation of the difference ranging from 11% to 17%.

Similar results were noted in a cohort of 67 patients with ischemic heart failure reported by **Gruszczynska K et al, 2012,** analyzing 2D echocardiography and CMR. Despite correlations between LVEDV and LVESV indices (0.85 and 0.83, P<.0001), significant absolute differences were noted between modalities, with LV volumes underestimated at 2D echo. Poor correlations were noted for LVEF (0.46, P = .001), which was overestimated at 2D echo.

In our study by eye balling or visual assessment of wall motion abnormalities, there is no significant difference between CMR and 2D echo in detection of the hypokinetic, akinetic and dyskinetic segments. The same results were obtained in a study by **(Nagel E et al 1999).**

Cardiac MR Limitations:

There are some limitations to CE-MRI, including costs, limited accessibility, and non-applicability in patients with pacemakers or implantable defibrillators. Furthermore, fears of gadolinium-induced nephrotic systemic fibrosis have recently resulted in restrictions of the technique in patients with renal insufficiency ***(Sadowski EA et al, 2007)***.

CONCLUSION

Cardiac MR imaging (CMR) is an accurate modality for the assessment of global left ventricular function. It accurately estimates EDV, ESV, SV, EF and wall motion abnormalities.

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