

Investigating the relationship between time-intensity curves produced by dynamic T1-W Cardiac Magnetic Resonance Perfusion imaging and early and late Gadolinium enhancement imaging in the diagnosis of Ischemia and its resulting infarct lesions

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ABSTRACT

Background and Objective: today, in the world of Cardiovascular Magnetic Resonance Imaging (CMR), another new technique, called Perfusion Weighted MRI, has been introduced that is widely used in the evaluation of the status of cardiac hemorrhage and probable ischemia. Unfortunately, the mentioned technique has only been qualitatively and visually examined in many CMR centers, while its highest potential has been for providing Time-Intensity Curves (TICs) and quantitative measurements. Such curves are also used in dynamic imaging of other parts of the human body including the pituitary gland and breast tissue. In this research, we examined the relationship between the curves obtained from the Perfusion Weighted MRI technique in the detection of myocardial infarction and myocardial ischemia lesions, and then, compared them with the Early and Late Gadolinium Enhancement CMR gold standards. **Methodology:** 20 patients with a history of coronary artery disease underwent MRI with a Siemens 1.5T machine. All patients had a normal renal function. The imaging process was performed in four stages: left ventricular imaging, perfusion imaging, early gadolinium enhancement imaging, and late gadolinium enhancement imaging. Then, indices of left ventricular function and related curves were evaluated using the CMR42 software. Finally, all curves were analyzed by two cardiothoracic radiologists. **Results:** 75 vascular territories in the examined 20 patients were studied; 26 territories were detected with clear ischemia, and 49 were detected with a normal coronary status. All curves extracted from those vascular territories were examined and compared regarding *simax* and time-to-peak indices in normal myocardium and myocardial infarction. The results indicated a significant difference between normal myocardium and cardiac infarct scar tissue in terms of the *simax* index; however, the difference was not statistically significant in terms of the time-to-peak index. **Conclusion:** it is a fact that 'no flow' zones, which are evaluated in early-contrast images, do not always result in scars in images with late-contrast. But scar tissues, which can be seen in late-contrast images, present themselves in early-contrast images as 'no flow' zones. In fact, the present study's evaluations were mainly done on late-contrast images. Given the significant difference in the *simax* index between normal myocardium and myocardial infarction, it can be concluded that our interpretation of myocardial infarction was based on highly accurate visual information. Even when there is a doubt about the presence of a vascular territory based on the available visual data, the doubt can be cleared by quantifying the analysis based on the *simax* index.

Keywords: Myocardial Ischemia, Myocardial Infarction, perfusion Dynamic images, images with early injection, images with late injection.

Introduction

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Heart attack or myocardial infarction is the permanent and irreversible death of a part of the heart muscle (myocardium); it occurs when blood flow decreases or stops to a part of the heart and causes myocardial ischemia or hypoxia in that part. The stop in blood circulation may occur suddenly and without any previous symptoms, or after several attacks of angina pectoris. The leading cause of myocardial infarction is a blockage of the arteries that supply blood to the heart muscle (coronary artery stenosis). Based on the clinical considerations, this blockage can be treated by medication, interventions or open heart surgery (Coronary Artery Bypass Grafting (CABG)). Myocardial infarction is a common complication that causes thousands of deaths each year. Diabetes, hypertension, high blood cholesterol, lack of physical activity, excessive smoking and alcohol use, nervous pressures, family history, and age can be mentioned as the most important predisposing factors of myocardial infarction. As a prevalent disease, myocardial infarction caused more than 150,000 deaths in the United States alone in 2004 [1].

The identification of myocardial infarction is easy sometimes, but there are occasions when it cannot be easily detected. Acute myocardial infarction can be easily detected in people who have a number of risk factors for atherosclerosis along with symptoms of ischemia. Patients suspected of having a heart attack are typically transferred to the Emergency Room (ER). When the clinical evidence suggests a heart attack, several diagnostic tests will be run immediately. These tests include Electrocardiography (ECG), blood sample test, and Echocardiography. The first diagnostic test is ECG, indicating an occurring or previously occurred heart attack. Concerning laboratory tests, there are tests associated with the specialized functions of living cells containing enzymes and proteins (e.g., Creatine kinase (CK), Troponin, & Myoglobin (MB)). A necrotic heart cell loses its membrane integrity, and therefore, enzymes and proteins can slowly enter the bloodstream. Such enzymes and proteins can be identified through laboratory methods. Echocardiography is performed for the detection of normal or abnormal contractility in the left ventricle. When the blood flow is reduced, one of the first measures of myocardial cells is to shut down the mechanism of energy demand for contraction. This process begins immediately after a decrease in the blood flow. Electrocardiography can be helpful in identifying the heart cells that are affected by a heart attack or

performance, CMR can provide valuable information about the site of myocardial ischemia or infarction. CMR shows the heart performance and texture morphology in an excellent way; moreover, the Late and Early Gadolinium Enhancement CMR can be used to determine the exact location of an infarct or ischemic region [4]. Today, in the world of CMR, another new technique, called Perfusion Weighted MRI, has been introduced, which is widely used in the evaluation of cardiac hemorrhage and probable ischemia. Unfortunately, the mentioned technique has only been qualitatively and visually examined in many CMR centers, while its highest potential has been for providing TICs and quantitative measurements. Such curves are also used in dynamic imaging of other parts of the human body including the pituitary gland and breast tissue. In this research, the relationship between the curves obtained from the Perfusion Weighted MRI technique were examined in the detection of myocardial infarction and myocardial ischemia lesions, and then, they were compared with the Early and Late Gadolinium Enhancement CMR gold standards.

In 2013, a review article on the role of CMR in the diagnosis of ischemia was published in the Methodist DeBakey Cardiovascular Journal. The article addressed the theoretical and practical aspects of CMR protocols in the diagnosis and examination of myocardial ischemic lesions. Moreover, the quantitative assessments of CMR in Perfusion imaging -such as using the variables of time-to-peak, mean transient time, upslope, and upslope ratio- were discussed in the mentioned article [5]. A similar study to the present research was published in 2013 in the RadoGraphics Journal. In this review study, the theoretical and practical aspects of various CMR protocols in the diagnosis of myocardial infarction follow-ups were discussed. In that study, the vital role of perfusion MRI in the diagnosis and prognosis of myocardial infarctions were pointed out; but, only the application of visual assessment of perfusion MRI was discussed in the article and the ways of its quantitative assessment were overlooked [6].

In 2007, another study was published on perfusion cardiac MRI in the Journal of Magnetic Resonance Imaging and under the supervision of the MRI Association. The paper addressed various aspects and usages of perfusion CMR in the diagnosis of cardiac ischemia in two phases of at rest and under stress (by injecting vasodilators). In the mentioned article, the upslope index was referred to as one of the most important quantitative variables of perfusion MRI [7].

In 2013, another article was published in the Journal of Nuclear Cardiology on the quantitative role of perfusion CMR in determining myocardial perfusion reserve and myocardial blood flow in comparison with the role of Positron Emission Tomography (PET) technique. In the discussion section of this article, it has been explained that perfusion MRI is able to calculate many quantitative cardiovascular indices (e.g., myocardial perfusion reserve & myocardial blood flow), and that this technique has a very high accuracy compared to the gold PET standard [8].

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in detecting the vessels which are probably blocked [2, 3]. In addition to Electrocardiography that can only show the heart

Methodology

Procedure

In this research, the quantitative results of CMR perfusion were compared with visual results of Early and Late Gadolinium Enhancement CMR to find a relevant pattern between the two methods. A summary of the research process will be presented as follows:

- Randomly selecting 20 patients out of patients diagnosed with viable myocardium and referred to Shahid Rajaei Cardiology Center;
- Explaining the risks and the research process to all participants;
- Obtaining written and verbal consent from the participants;
- Performing CMR as follows:
 - ✓ 3 Plane 2D True-Fisp Localizer
 - ✓ 2Chamber, 3 Chamber, 4 Chamber, Short-Axis, RVOT Retrospective Cine 2D True-Fisp MR Imaging
 - ✓ 4 Chamber, 2 Chamber, Short-Axis Short-Tau-Inversion-Recovery (STIR) MR Imaging
 - ✓ Dynamic T1w Fast-Low-Angle-Shot Contrast Enhanced Perfusion Short-Axis MR Imaging
 - ✓ Early True-Fisp post-Gd MR Imaging
 - ✓ Late phase-sensitive inversion recovery post-Gd MR Imaging (TI=200 to 50)
- Comparing Early and Late post-Gd enhancement images with TICs obtained from Perfusion Weighted MRI.

Instrument

- **1.5T cardiac specified Avanto scanner (Siemens, Erlangen, Germany)**

All perfusion data were extracted using the CMR42 and MATLAB software. Then, two radiologists compared the different curve patterns with Early and Late Gadolinium Enhancement images and reported the results. The quantitative data were reported by a clinical CMR physician, and then, statistically analyzed.

Results

In the present study, 75 vascular territories were studied: 26 territories were detected with clear ischemia and 49 with a normal coronary status. All curves extracted from those vascular territories were examined and compared in terms of simax and time-to-peak indices in normal myocardium and myocardial infarction. The results indicated a significant difference between normal myocardium and cardiac infarct scar tissue in terms of the simax index ($p=0.007$); however, the difference was not statistically significant in terms of the time-to-peak index ($p=0.083$).

The procedure, performed on each patient, is presented in the following images:

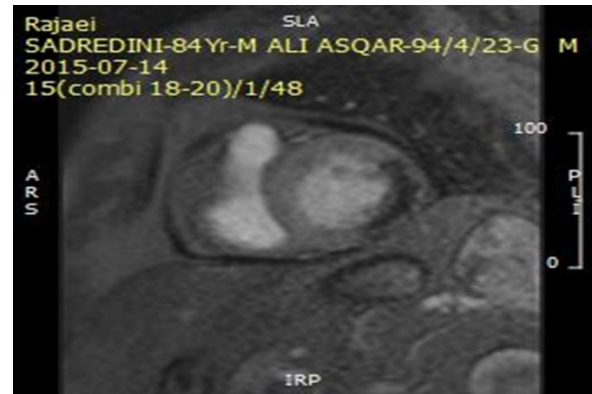


Figure 1: Hypoperfusion region in LCX territory in Dynamic T1-w CMR Perfusion images

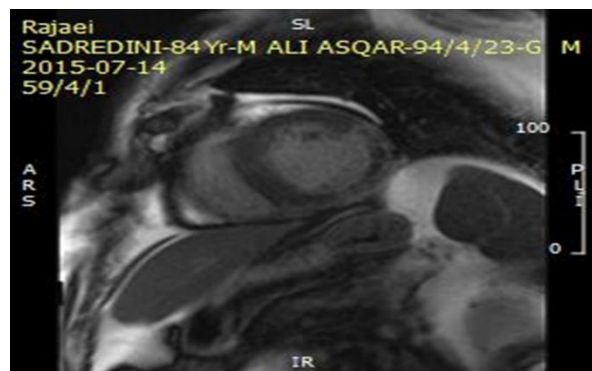


Figure 2: Infarct area in LCX territory in Late Gadolinium Enhancement images

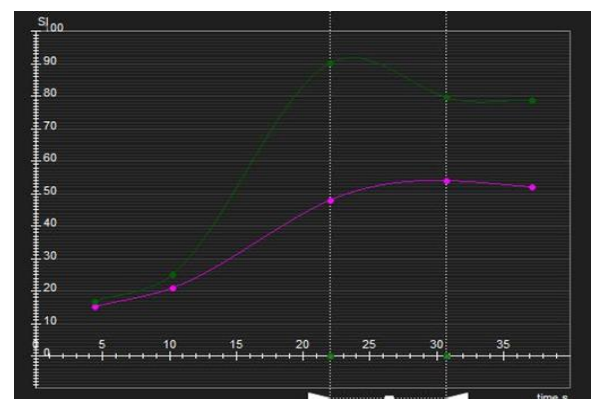


Figure 3: TICs in hypoperfusion regions and regions with normal perfusion
Green curve: TIC of normal regions
Purple curve: TIC of hypoperfusion regions

Table 1. The number of curves in normal and infarct areas

		Group Statistics			
	myocardium	N	Mean	Std. Deviation	Std. Error Mean
time	normal	49	37.8367	9.01930	1.28847
	infarct	26	41.7692	11.42736	2.24109
Simax	normal	49	118.4082	79.03478	11.29068
	infarct	26	70.2692	17.79788	3.49045

Table 2. Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		
										Lower	Upper
time	Equal variances assumed	3.094	.083	-1.635	73	.1062534937169	-3.93250	2.40449	-8.72464	.85965	
	Equal variances not assumed			-1.521	41.876	.1357186730455	-3.93250	2.58508	-9.14986	1.28487	
Simax	Equal variances assumed	7.613	.007	3.056	73	.0031347714974	48.13893	15.75376	16.74174	79.53613	
	Equal variances not assumed			4.073	56.620	.0001457447696	48.13893	11.81790	24.47055	71.80731	

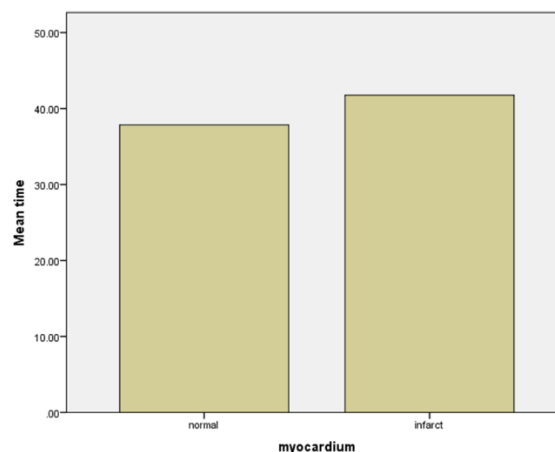
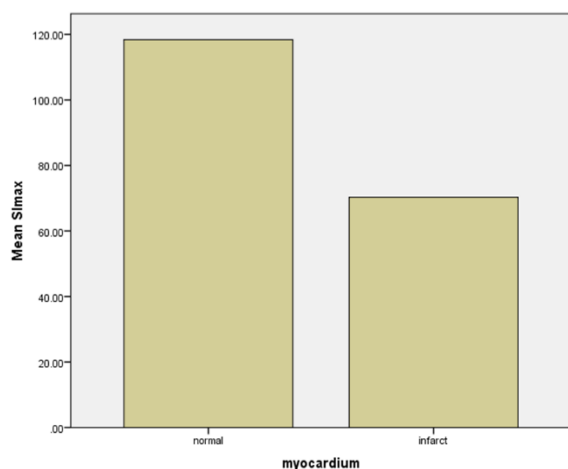


Figure 4:

Discussion and Conclusion

The fact is that 'no flow' zones, which are evaluated in early-contrast images, do not always result in scars in images with late-contrast. But scar tissues, which can be seen in late-contrast images, present themselves in early-contrast images as 'no flow' zones. In fact, the present study's evaluations were chiefly done on late-contrast images. Given the significant difference in the simax index between normal myocardium and myocardial infarction, it can be concluded that the present study's interpretation of myocardial infarction was based on highly

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accurate visual information. Even when there is a doubt about the presence of a vascular territory based on the existing visual data, the doubt can be eliminated by quantifying the analysis based on the simax index.

References

1. Mehta, PK; Wei, J; Wenger, NK. "Ischemic heart disease in women: A focus on risk factors". *Trends in Cardiovascular Medicine* 25 (2): 140–151. doi: 10.1016/j.tcm.2014.10.005. December 17, 2013. Retrieved 24 February 2015.
2. Bolooki HM, Askari A. Acute myocardial infarction. *Cleveland Clinic On line*. 2010.
3. "How Is a Heart Attack Diagnosed?". <http://www.nhlbi.nih.gov/>. December 17, 2013. Retrieved 24 February 2015.
4. Martina Perazzolo Marra, João A.C. Lima, Sabino Iliceto. "MRI in acute myocardial infarction". *Eur Heart J*. 2011 Feb; 32(3):284-93. doi: 10.1093/eurheartj/ehq409. Epub 2010 Nov 25.
5. Caroline Daly, Raymond Y. Kwong. "Cardiac MRI for Myocardial Ischemia". *Methodist DeBakey Cardiovasc J*. 2013 Jul-Sep; 9(3): 123–131.
6. Prabhakar Rajiah, Milind Y. Desai, Deborah Kwon, Scott D. Flamm. "MR Imaging of Myocardial Infarction" *RadioGraphics* 2013; 33:1383–1412.
7. Hajime Sakuma. "Magnetic resonance imaging for ischemic heart disease". *Jour of Mag Res Imag* 26:3–13 (2007).
8. Bratis K, Mahmoud I, Chiribiri A, Nagel E. "Quantitative myocardial perfusion imaging by cardiovascular magnetic resonance and positron emission tomography". *J Nucl Cardiol*. 2013 Oct ; 20(5) : 860-70.