ISSN 2394–806X (Print), ISSN 2454-5139 (Electronic)
IJHRMLP, Vol: 04 No: 01 January, 2018
Printed in India

REVIEW PAPER

Rationale behind using stress MRI over nuclear imaging for cardiac ischemia evaluation

Baruah Dhiraj[1], Gupta Nishant[2], Boruah Pranjal[3], Shahir Kaushir[4]

Received on *December 14, 2016;* ***editorial approval*** *on August 18, 2017*

ABSTRACT

Introduction*: There are different methods for evaluating cardiac ischemia in a noninvasive way, most commonly used is nuclear stress testing. Another commonly performed investigation to evaluate coronary artery disease in symptomatic patients is coronary CT angiography. On one hand, coronary CT angiography provides anatomic information and stress testing using different modalities provides physiologic information. This physiologic information plays an important role in patient management than mere anatomic narrowing seen on CT angiography.* ***Objectives****: In this article, we are highlighting the role of cardiac MRI in this critical situation and its value over nuclear stress test. We will also discuss how cardiac MRI can help obtaining more added informations and obtaining differential diagnosis not always possible with nuclear imaging.* ***Discussion****: With continued advancement of MRI, stress MRI imaging is becoming another important modality and frequently used now a day to look for cardiac ischemia. This imaging modality provides physiologic information as stress nuclear imaging and also provides anatomic information. Delayed contrast enhanced imaging with MRI helps identifying areas of scar tissue and quantifying areas of viability. With MRI characterization of ischemic vs. non-ischemic cardiomyopathy is possible.* ***Conclusion****: On this article, we are highlighting the role of cardiac MRI evaluating cardiac ischemia and its value over nuclear stress test.*

Keywords*: Coronary Artery Disease, Ischemic Heart Disease, Stress Cardiac MRI*

INTRODUCTION

Evaluating cardiac ischemia and timely intervention helps preventing catastrophic effect of coronary artery disease. Clinical and electrocardiographic (ECG) evaluations are not always optimal to assess cardiac ischemia.[1] In fact; stress echocardiography is also significantly limited for this. While conventional catheter angiography remains the gold standard for diagnosis and management of an acute ischemic event, there are several noninvasive modalities for patients with chronic ischemic heart disease. These include stress echocardiography, treadmill ECG, and nuclear perfusion. More recently, coronary computed tomography angiography (CTA) has gained lot of importance as it has an advantage of detecting coronary anatomy and stenosis. However, perfusion imaging is one of the modality to evaluate physiologic effect of the vascular stenosis seen in CTA. In many places, nuclear stress imaging is currently one of the commonest investigations to image chronic ischemic heart disease, stable angina, etc. With the continued advancement of pulse sequences, hardware and image reconstruction methods cardiac MRI (Magnetic Resonance Imaging) perfusion scans play an important role in current day practice.

Indications of Cardiac MRI Stress Perfusion

Commonest indication of stress cardiac MRI is for evaluation of patients with chest pain syndromes who have intermediate probability of coronary artery disease (CAD).

Some other indications includes: Chronic angina, Patient with possible non-ischemic cardiomyopathy to rule out ischemic cause

Address for correspondence:
[1]Chief, Cardiothoracic Radiology (**Corresponding Author**)
Medical Director, Emergency Radiology
Co-director, Cardiac MRI
Medical College of Wisconsin, Milwaukee, USA
Email: dhirajbaruah@gmail.com, dbaruah@mcw.edu
Mobile: +14145735468
[2]Fellow, Columbia University Medical Center
New York, USA
[3]Assistant Professor, Geisinger Commonwealth School of Medicine
Cardiology Associate, Geisinger Cardiology, Pennsylvania, USA
[4]Associate Professor, University of South Florida, Tampa, Florida, USA

and when other imaging modalities are contraindicated (e.g. poor echocardiography window in obese patients).

Contraindications of Cardiac MRI Stress Perfusion

Absolute:

1. **Asthma** (ongoing wheezing): However, there are reports of performing adenosine stress test in asthma patients who are adequately controlled. Bronchodilator inhalers are commonly used as premedication.

2. **Heart block**: Second or third degree.

3. **Medications**: Dypridamole should be stopped for 24 hours before and Methylxanthenes and products containing Methylxanthenes (coffee) should be stopped 12 hours before study.

4. Previous severe allergy to adenosine.

5. Systolic blood pressure less than 90 mm Hg.

6. Unstable angina or ACS (acute coronary syndrome).

Relative: Sinus bradycardia with a heart rates < 40 beats/minutes.

PERFORMING A STRESS CARDIAC MRI

1. **Patient preparation**: Patient should be empty stomach for 2 hours before the test. Patient should not drink any caffeine-containing drinks for at least 12 hours prior to the testing. Electrocardiography should be done before and after test. A nurse should evaluate vitals including Pulse, Respiratory rate, Temperature, Blood pressure, etc. Technologist should check for any metallic devices or foreign body with the patient.

2. **Contrast**: For evaluation of cardiac perfusion contrast injection is necessary. The perfusion technique is based on passage of an intravenous injection of bolus gadolinium through myocardium. Gadolinium lowers the T1 property of tissues and gives bright signal on perfusion images.[2] Hence, perfused areas will be relatively bright as compared to the areas with decreased or absent perfusion. This also depends on amount of gadolinium extraction, which is around 0.5 for extracellular gadolinium contrast agents.[3] Myocardial perfusion can be evaluated with cardiac MRI in both qualitative and quantitative methods. There are currently established intravascular contrast agents for cardiac MRI stress perfusion.[4]

3. **MRI Pulse sequences**: As mentioned earlier, T1 contrast is affected significantly due to presence of gadolinium and MR perfusion images are heavily T1 weighted sequences to take advantage of this property. Images are acquired rapidly in the R-R interval with cardiac gating. Depending on the heart rate the R-R interval varies, and 3 to 5 slice locations are possible to acquire perfusion images. Images need to have good spatial resolution to detect subtle changes of perfusion in the subendocardial location. The information can be obtained with inversion recovery (IR) or nonselective saturation recovery (SR) sequences. SR sequences are commonly used due to shorter preparation time and possibility of doing multiple slices at the same time.[5] With advancement of MRI techniques; parallel imaging is routinely used to have faster scanning and better coverage.[3] Tesla MRI is really helpful as compared to 1.5 Tesla scanners.[6] Detailed description of pulse sequences is beyond

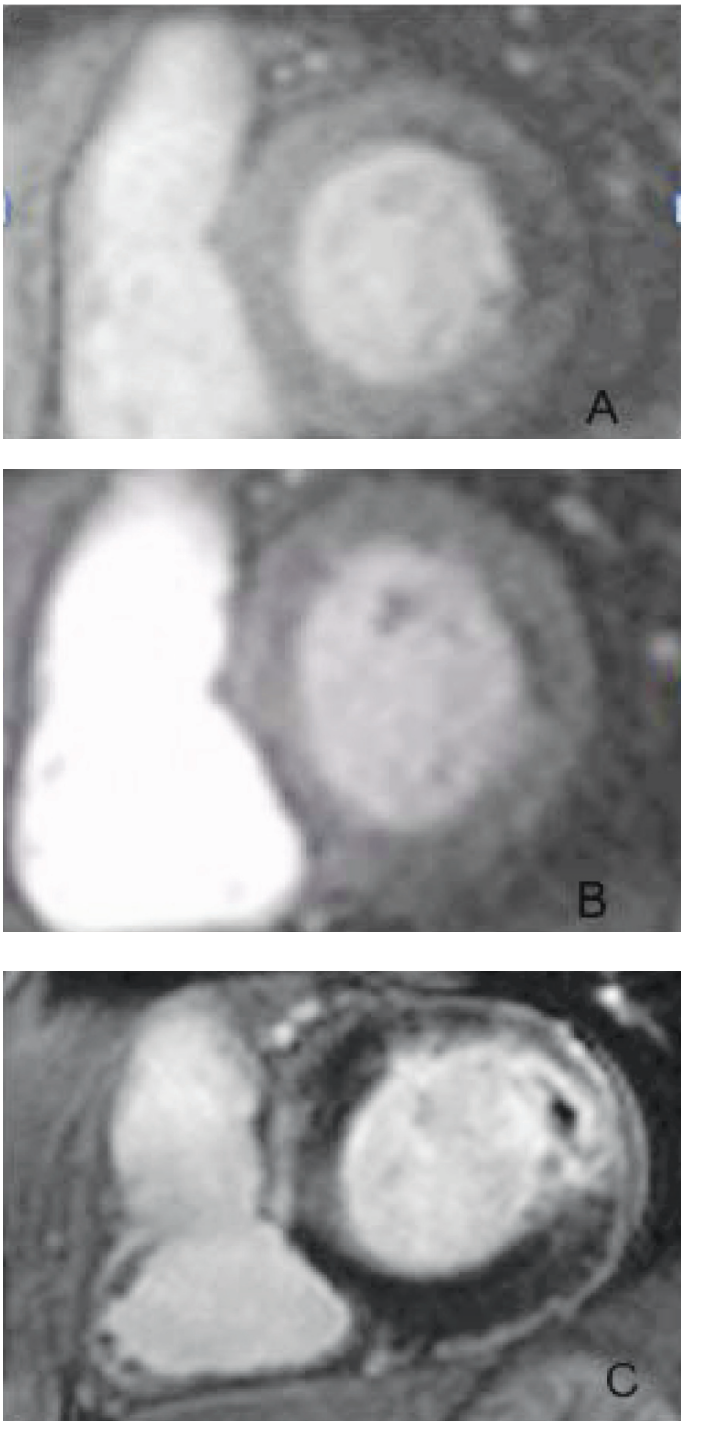

Figure 1 Stress MRI showing perfusion defect and ischemia. Stress perfusion **(Figure 1A)** showing dark area involving lateral wall suggesting left circumflex territory is chemia. There is a smaller dark area in the corresponding lateral wall on rest perfusion **(Figure 1B)** suggesting small area of resting perfusion abnormality. Delayed enhancement image **(Figure 1C)** showing enhancing lateral wall infarct with internal small hypointensity suggesting microvascular obstruction. Region of perfusion abnormality (1A) is more than enhancement (1C) or resting perfusion defect (1B) suggesting infarct with surrounding stress-induced is chemia.

the scope of this article and interest of this journal.

4. **Scanning Protocol**: MRI stress perfusion imaging is usually done with other basic scans to evaluate cardiac function and delayed enhancement. Most commonly the agent used for stress imaging is adenosine (140 ìg/kg/min) for duration of 2 to 4 minutes in a rate of 3 to 4 ml/s. A total of 40 – 60 dynamic image frames are obtained. Usually stress perfusion alone is adequate for evaluating ischemia. However, for evaluation of quantitative perfusion values similar perfusion images are also obtained at rest (without injection of adenosine). Stress perfusion can also be done using dobutamine. Some advanced centers are now trying treadmill stress for cardiac perfusion MRI.[7]

5. **Evaluating images**: Both quantitative and qualitative evaluations of stress images possible. Most of the centers worldwide use semi automated softwares for evaluating cardiac perfusion along with functional and delayed enhancement parameters. Overall sensitivity and specificity of evaluating cardiac ischemia using delayed enhancement, stress and rest images are 89% to 87% respectively.[8] Different quantitative parameters can be evaluated with cardiac MRI including time to peak, upslope, peak myocardial enhancement and subepicardial to subendocardial gradient. Using deconvolution method, absolute quantification is possible.[9] In general, darker areas in stress perfusion images without abnormal delayed enhancement and normal rest perfusion suggests areas of ischemia (**Figure 1**).

Advantages of cardiac MRI over nuclear stress test

1. Cardiac MRI is much faster as compared to nuclear stress imaging. On an average, stress cardiac MRI examinations take 30-40 minutes and nuclear stress test takes about four hours.

2. MRI is free of radiation. However, nuclear stress test exposes the patient to radiation.

3. Cardiac MRI has significantly higher spatial resolution as compared to nuclear perfusion.

4. Cardiac MRI provides absolute quantification of perfusion and also additional information including cardiac viability, function and morphology. These parameters are evaluated with cardiac MRI at a much higher resolution as compared to nuclear stress imaging or stress echocardiography.

5. Cardiac stress MR has no significant operator dependence.

6. Cardiac stress MR signal intensities are largely independent of patient's body habitus.

7. Cardiac stress MRI also evaluates myocardial viability similar to PET study without exposing the patient to radiation.

8. MRI can give us alternative diagnosis, which may not be possible with other imaging modalities.

Limitation of cardiac MRI

1. Dark rim artifact – Sometimes, presence of this artifact can mimic an area of perfusion abnormality. This artifact can be due to cardiac motion, limitation of resolution or susceptibility.[10, 11, 12] This artifact usually disappears during the equilibrium phase of imaging.

2. Limitation of rest perfusion if performed after stress – gadolinium retention in areas after stress perfusion limits evaluation of stress images. However, combined evaluation of delayed enhancement with perfusion imaging helps understanding rest perfusion images.

3. Renal failure patient: Gadolinium is contraindicated in a patient with elevated creatinine and an estimated GFR of less than 30 due to the risk of a rare condition called nephrogenic systemic fibrosis, which may be life threatening.[13] However, dobutamine stress MRI could still be an option. Newer T1 sequences are being developed which depict changes with adenosine stress without using Gd contrast.

How to use Cardiac stress MRI in clinical practice

There are available guidelines in the literature for appropriate use of contrast enhanced cardiac MRI including stress MRI for evaluating ischemia.[14] Adenosine stress MRI with intermediate risk patients for cardiac ischemia has a sensitivity of 0.91(95% CI, 0.88 to 0.94) and specificity of 0.81(95% CI, 0.77 to 0.85).[15] Another way to look at the usefulness of cardiac MRI is event rate in patients with known or suspected coronary artery disease. In this group of patient's abnormal stress cardiac MRI has an event rate of 17% compared with 5% with a normal study.[16] Another functional parameter for cardiac is chemia evaluation is measurement of Fractional Flow Reserve (FFR), either with catheter angiography or recently with Computed Tomography (CT). There is a good correlation of cardiac MRI perfusion with FFR by catheter angiography, helping to make a decision of managing cardiac ischemia noninvasively.[17] There are studies comparing contrast enhanced cardiac MRI absolute perfusion reserve with Positron Emission Radiography (PET) and this may be a future direction for evaluating cardiac is chemia.[18]

Acknowledgement: The authors thank Carrie L Gilbert, Administrative Assistant for helping with preparing the article in the required journal format.

REFERENCES

1. Hendel RC, Patel MR, Kramer CM, Poon M, Carr JC, Gerstad NA, et al. ACCF/ACR/SCCT/SCMR/ASNC/NASCI/SCAI/SIR 2006 appropriateness criteria for cardiac computed tomography and cardiac magnetic resonance imaging. J Am Coll Cardio 2006;48:1475–97.
2. Weinman HJ, Brash RC, Press WR, Wesley GE. Characteristics of gadolinium-data complex: a potential nmr contrast agent. AJR Am J Roentgen 1984;142:619–24.
3. Gould KL, Kelley KO, Bolson EL. Experimental validation of quantitative coronary arteriography for determining pressure-flow characteristics of coronary stenosis. Circulation 1982;66:930–7.
4. Jerosch-Herold M, Wilkes N, Wang Y, Gong GR, Mansoor AM, Huang H, et al. Direct comparison of an intravascular and an extracellular contrast agent for quantification of myocardial perfusion: cardiac MRI Group. Int J Cardiovascular Imaging 1999;15:453–64.
5. Saeed M, Higgins CB, Geschwind JF, Wend land MF. T1-

relaxation kinetics of extracellular, intracellular and intravascular MR contrast agents in normal and acutely reperfused infarcted myocardium using echo-planar MR imaging. Eur Radiol 2000;10:310–8.

6. Kellman P, Arai AE. Imaging sequences for first pass perfusion - a review. J Cardiovascular Magn Reson 2007;9:525–37.
7. Araoz PA, Glockner JF, McGee KP, Potter DD, Jr, Valeti VU, Stanley DW, et al. 3 Tesla MR imaging provides improved contrast in first-pass myocardial perfusion imaging over a range of gadolinium doses. J CardioVasc Magn Reson 2005;7:559–64.
8. Klem I, Heitner JF, Shah DJ, Sketch MH, Behar V, Weinsaft J, et al. Improved detection of coronary artery disease by stress perfusion cardiovascular magnetic resonance with the use of delayed enhancement infarction imaging. J Am Coll Cardiol 2006;47:1630–8.
9. Wilke N, Jerosch-Herold M, Wang Y, Huang Y, Christensen BV, Stillman AE, et al. Myocardial perfusion reserve: assessment with multisection, quantitative, first-pass MR imaging. Radiology 1997;204:373–84.
10. Schreiber WG, Schmitt M, Kalden P, Mohrs OK, Kreitner KF, Thelen M. Dynamic contrast-enhanced myocardial perfusion imaging using saturation-prepared true FISP. J Magn Reson Imaging 2002;16:641–52.
11. Di Bella EV, Parker DL, Sinusas AJ. On the dark rim artifact in dynamic contrast-enhanced MRI myocardial perfusion studies. Magn Reson Med 2005;54:1295–9.
12. Storey P, Chen Q, Li W, Edelman RR, Prasad PV. Band artifacts due to bulk motion. Magn Reson Med 2002;48:1028–36.
13. Prasad SR, Jagirdar J. Nephrogenic systemic fibrosis/ nephrogenicfibrosingdermopathy: a primer for radiologists. J Computer Assist Tomogr 2008;32:1–3.
14. Nandalur KR, Dwamena BA, Choudhury AF, Nandalur MR, Carlos RC. Diagnostic performance of stress cardiac magnetic resonance imaging in the detection of coronary artery disease: a meta-analysis. J Am Coll Cardiol 2007;50:1343–53.
15. Bodi V, Sanchis J, Lopez-Lereu MP, Nunez J, Mainar L, Monmeneu JV, et al. Prognostic value of dipyridamole stress cardiovascular magnetic resonance imaging in patients with known or suspected coronary artery disease. J Am Coll Cardiol 2007;50:1174–9.
16. Rieber J, Huber A, Erhard I, Mueller S, Schreyer M, Koenig A, et al. Cardiac magnetic resonance perfusion imaging for the functional assessment of coronary artery disease: a comparison with coronary angiography and fractional flow reserve. Eur Heart J 2006;27:1465–71.
17. Fritz-Hansen T, Hove JD, Kofoed KF, Kelbaek H, Larsson HB. Quantification of MRI measured myocardial perfusion reserve in healthy humans: a comparison with positron emission tomography. J Magn Reason Imaging 2008;27:818–24.
18. Waller AH, Blank stein R, Kwong RY, Di Carli MF. Myocardial blood flow quantification for evaluation of coronary artery disease by positron emission tomography, cardiac magnetic resonance imaging, and computed tomography. Current Cardiology Reports 2014;16(5):483.