MYOCARDIAL ISCHEMIA AND INFARCTION

Safety of Adenosine Stress Magnetic Resonance Imaging Using a Mobile Cardiac Magnetic Resonance System

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ABSTRACT

Background: Contrast-enhanced magnetic resonance imaging (ceMRI) allows for the detection of ischemic heart disease. Aim of this prospective study was to show feasibility, practicability and safety of adenosine stress ceMRI in routine outpatients with a mobile scanner. Methods: Consecutive patients were scanned in six different cardiac outpatient centers with a 1.5 T mobile ceMRI scanner. First-pass wash-in patterns of gadolinium chelate were evaluated after three minutes of adenosine infusion. After a second bolus of gadolinium chelate myocardial late enhancement (MLE) images of the left ventricle were acquired to visualize myocardial necrosis. Results: Five hundred seventy-four patients were enrolled to the study. No major complications during examination and adenosine infusion were observed. One hundred seventy-three minor complications as temporary atrio-ventricular blockade, mild chest pain or dyspnea and nausea were noticed. None of the complications led to further special treatment. Conclusion: This ceMRI protocol is suitable for application in outpatient settings. CeMRI stress testing using a mobile scanner in an outpatient setting is feasible and safe.

INTRODUCTION

Diagnosis and evaluation of ischemic heart disease is mandatory for guiding further treatment. Commonly used stress testings prior to invasive coronary artery (CA) angiography in routine outpatients are stress electrocardiography and echocardiography. These diagnostic methods do not provide direct information about myocardial perfusion. Positron emission and single photon emission computed tomography on the other hand suffer from attenuation artifacts and limited spatial resolution (1–3). Several studies have shown that contrast-enhanced magnetic resonance imaging (ceMRI) with pharmacologically provoked stress has a higher spatial and temporal resolution and is suitable to answer the question of myocardial perfusion with a high sensitivity and specificity (4–7). Furthermore, ceMRI provides information about myocardial viability which is necessary for further therapy decision (7–12). However, there is little knowledge about the practicability and safety of adenosine stress ceMRI in outpatients, especially regarding with examinations of patients from different centers with a single mobile ceMRI scanner.

The aim of our study was to demonstrate the feasibility, practicability and safety of stress perfusion ceMRI in a multi-center outpatient setting with one mobile ceMRI machine.

METHODS

Study population

We prospectively enrolled consecutive patients from six German outpatient centers with suspected ischemic heart disease.
disease over the period of 12 months. Patients with unstable angina or myocardial infarction or CA revascularization within the last six months, higher degree of heart valve disease, higher degree of atrio-ventricular blocks, acute myocarditis, internal pacemaker or defibrillator, and inability to give written informed consent were excluded from the study. Local ethical committees in Berlin and ethic committees of the medical associations responsible for the locations where CMR examinations were performed approved the study protocol. Written informed consent was obtained from all patients.

Study protocol

All patients were examined clinically and cardiovascular risk factors were assessed. A 12-lead surface ECG was obtained in each patient. Arterial blood pressure, heart rate and oxygen saturation were monitored non-invasively during adenosine infusion. All patients had to stop antianginal medication 24 hours and caffeinated food or beverages and 48 hours before examination. Mild sedation with midazolame (1 mg) was offered in case of anxiety or claustrophobia.

Magnetic resonance examination

All ceMRI studies were performed with a 1.5 Tesla whole-body system (Signa TwinSpeed, GE Medical System, Milwaukee, USA) with a 4-element phased array surface coil (Cardiac coil, GE Medical Systems) assembled on a trailer (Figs. 1 and 2) (13.65 m length, 2.6 m width, 4.00 m height, 37 t weight). All studies were performed by special trained technical assistants, and at each center, a trained cardiologist was present during the examination. Each of the cardiac outpatient centers examined their consecutive patients once a month. All of the following sequences were performed in end-expirational breath-hold. Functional imaging with steady-state free precession sequences were acquired in three long axis and in contiguous short axis orientation to cover the left ventricle from the basis to the apex (TR 5.1 ms, TE 2.2 ms, flip angle 60°, matrix 256 × 192, slice thickness 8 mm, no interslice gap, field of view 32–34 × 24–25.5 cm, every RR-Interval), and images in 5 continuous short axis orientations were acquired. Adenosine-infusion was stopped after the perfusion sequence. Ten minutes after intravenous injection of a second bolus of 0.1 mmol/kg body-weight gadoteric acid, inversion-recovery gradient-echo sequences were acquired (TR 7.1 ms, TE 3.2 ms, flip angle 20°, TI 180–240 ms, slice thickness 8 mm, no interslice gap, matrix 256 × 160, field of view 32–34 × 32–34 cm) for myocardial late enhancement visualization. Contiguous slices in short axis orientation from the basis to the apex of the left ventricle were acquired. All side effects and complications during and one hour after adenosine infusion were recorded correspondingly.

CeMRI analysis

Two investigators examined all ceMRI studies. Analysis of the images was performed with the standard software provided by the manufacturer of the MRI system (Advantage Workstation, GE Medical System). Left ventricular ejection fraction and left ventricular mass were calculated using the short axis data of the steady-state free precession sequences (13). Qualitative assessment of the perfusion images using the 16-segments model of AHA (14) was performed. All segments were evaluated for hypoperfusion during first-pass perfusion. Areas of perfusion deficits were assigned to the corresponding coronary artery using the model of AHA (14). Analysis of myocardial late enhancement was performed visually. Bright areas, regarded as non-viable fibrotic tissue were assessed using above mentioned 16-segments mode.

RESULTS

Five hundred ninety-five patients were screened for enrollment to the study. Twelve patients were excluded due to unstable angina and 9 due to heart valve disease. All patients gave written informed consent and 750 patients were included in the study. The mean age was 60 years (SD 10 years), 49% of the patients were male. The mean body weight was 85 kg (SD 15 kg). Twenty percent of the patients were hypertensive. Of the patients, 61% had a history of myocardial infarction, 25% of the patients had undergone previous CABG surgery and 40% had undergone percutaneous revascularization. The mean left ventricular ejection fraction was 52% (SD 10%).

Figure 1. Trailer transporting the MRI system.

Figure 2. Trailer interior—MRI setting.
Feasibility and safety of the underlying protocol was demonstrated in 574 outpatients. No major complications and only few minor complications resolved within minutes after examination observed. Five hundred seventy-four patients formed the study group. Seven patients (1.2%) had claustrophobia and were offered mild sedation. In all of latter mentioned patients, ceMRI study could be completed.

**Magnetic resonance examination**

Adenosine-stress ceMRI could be performed in all patients. No patient experienced a major complication. Temporary atrioventricular blockade during adenosine infusion could be observed in 64 (11%) patients, 78 (14%) patients reported of mild chest pain and/or dyspnea, and 31 (5%) patients suffered from emesis or nausea (Table 1). All minor complications resolved within a few minutes and did not lead to further special therapy.

Image quality was sufficient for further analysis in all patients. However, not all patients were able to perform breathhold for the entire first-pass perfusion sequence. Consequently, image quality in these patients was reduced but still diagnostic. Accurate assessment was not possible in one case due to reduced image quality. Interobserver agreement was very high ($\kappa = 0.94$).

Procedure length for the compiled ceMRI protocol was 27 ± 8 minutes including adenosine-stress testing.

**DISCUSSION**

This study is the first to report an integrated ceMRI protocol for the assessment of myocardial perfusion, and myocardial viability that has been evaluated for its practicability and safety in a multi-center outpatient setting with a mobile ceMRI scanner. Feasibility and safety of the underlying protocol was demonstrated in 574 outpatients. No major complications and only few minor complications resolving within minutes after examination were observed.

Aim of our study was not demonstrate the ability of ceMRI to visualize extent and location of hypoperfusion and/or nonviable myocardial tissue as these diagnostic aspects have been answered extensively by previous studies. Advantages of ceMRI over all other available techniques are high spatial and temporal resolution without anatomical limitations and the ability to cover the entire left ventricle in reproducible slice orientations (1–3, 5, 13). Measurement of MLE with a fixed instead of an individually adjusted inversion time as in our protocol has been also published to be suitable to detect fibrosis safely but with slightly reduced image quality in previous studies (15–18).

Feasibility and practicability of ceMRI in an outpatient setting was proven in only one recently published study demonstrating a practicable ceMRI approach in an outpatient setting showing ceMRI to be a competitive method to radionuclide ventriculography and echocardiography in terms of procedure length and reproducibility (19). Efficiency of their ceMRI clinic was demonstrated in 64 patients with heart failure and concluded that ceMRI can provide a rapid and reproducible assessment of cardiac function in those patients. However, in their study only cardiac function was assessed and procedure time still was 42 ± 4 min compared to 27 ± 8 minutes in our study. Myocardial perfusion and viability were not assessed.

In contrast, our study focused on the detection of inducible ischemia in patients with suspected or known ischemic heart disease. Our study protocol allows for the assessment of multiple aspects of ischemic heart disease in outpatients in one single compiled examination. Information about cardiac function, myocardial perfusion and viability was given in all patients which is necessary for guiding further treatment in these patients.

**CONCLUSIONS**

Our compiled protocol for diagnosis of ischemic heart disease with a mobile ceMRI scanner in a multi-center outpatient population is a practicable and safe approach. Adenosine-stress ceMRI could be thus used in outpatient centers complementary or as a surrogate for other stress testings without complications.

**ACKNOWLEDGMENTS**

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**ABBREVIATIONS**

CA Coronary Artery  
ceMRI Contrast-enhanced Magnetic Resonance Imaging

**REFERENCES**


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