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Quantification of myocardial perfusion using cardiac magnetic resonance imaging correlates significantly to rubidium-82 positron emission tomography in patients with severe coronary artery disease: A preliminary study

Abbas A. Qayyum[a,*], Philip Hasbak[b,1], Henrik B.W. Larsson[b,c,2], Thomas E. Christensen[b,3], Adam A. Ghotbi[b,4], Anders B. Mathiasen[a,5], Niels G. Vejlstrup[a,6], Andreas Kjaer[b,7], Jens Kastrup[a,8]

[a] *Department of Cardiology & Cardiac Catheterization Laboratory 2014, The Heart Centre, Rigshospitalet, University Hospital of Copenhagen and Faculty of Health Sciences, Copenhagen University, Blegdamsvej 9, 2100 Copenhagen, Denmark*
[b] *Department of Clinical Physiology, Nuclear Medicine & PET, Rigshospitalet, University Hospital of Copenhagen and Faculty of Health Sciences, Copenhagen University, Blegdamsvej 9, 2100 Copenhagen, Denmark*
[c] *Functional Imaging Unit, Diagnostic Department, Glostrup Hospital, University Hospital of Copenhagen and Faculty of Health Sciences, Copenhagen University, Ndr. Ringvej 57, 2600 Copenhagen, Denmark*

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ABSTRACT

Introduction: Aim was to compare absolute myocardial perfusion using cardiac magnetic resonance imaging (CMRI) based on Tikhonov's procedure of deconvolution and rubidium-82 positron emission tomography (Rb-82 PET).
Materials and methods: Fourteen patients with coronary artery stenosis underwent rest and adenosine stress imaging by 1.5-Tesla MR Scanner and a mCT/PET 64-slice Scanner. CMRI were analyzed based on Tikhonov's procedure of deconvolution without specifying an explicit compartment model using our own software. PET images were analyzed using standard clinical software. CMRI and PET data was compared with Spearman's rho and Bland–Altman analysis.
Results: CMRI results were strongly and significantly correlated with PET results for the absolute global myocardial perfusion differences ($r = 0.805$, $p = 0.001$) and for global myocardial perfusion reserve (MPR) ($r = 0.886$, $p < 0.001$). At vessel territorial level, CMRI results were also significantly correlated with absolute PET myocardial perfusion differences ($r = 0.737$, $p < 0.001$) and MPR ($r = 0.818$, $p < 0.001$). Each vessel territory had similar strong correlation for absolute myocardial perfusion differences (right coronary

Abbreviations: BMI, body mass index; BP, blood pressure; CABG, coronary artery bypass grafting; CAD, coronary artery disease; CI, confidence interval; CMRI, cardiac magnetic resonance imaging; HR, heart rate; ICA, invasive coronary angiography; LAD, left anterior descending artery; LCX, left circumflex artery; MPR, myocardial perfusion reserve; n, number; PCI, percutaneous coronary intervention; Rb-82 PET, rubidium-82 positron emission tomography; RCA, right coronary artery; s.d., standard deviation; SPECT, single-photon emission computed tomography.

* Corresponding author. Tel.: +45 3545 1076; fax: +45 3545 2805.
E-mail addresses: abbas.ali.qayyum@regionh.dk (A.A. Qayyum), philip.hasbak@regionh.dk (P. Hasbak), henrik.larsson@regionh.dk (H.B.W. Larsson), thomas.emil.christensen@regionh.dk (T.E. Christensen), adam.ali.ghotbi@regionh.dk (A.A. Ghotbi), anders.b.mathiasen@gmail.com (A.B. Mathiasen), niels.vejlstrup@regionh.dk (N.G. Vejlstrup), andreas.kjaer@regionh.dk (A. Kjaer), jens.kastrup@regionh.dk (J. Kastrup).
[1] Tel.: +45 3545 0815.
[2] Tel.: +45 3863 2432.
[3] Tel.: +45 3545 1086.
[4] Tel.: +45 3545 8602.
[5] Tel.: +45 3545 0673.
[6] Tel.: +45 3545 0924.
[7] Tel.: +45 3545 4216.
[8] Tel.: +45 3545 2819.

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artery (RCA): $r = 0.787$, $p = 0.001$; left anterior descending artery (LAD): $r = 0.796$, $p = 0.001$; left circumflex artery (LCX): $r = 0.880$, $p < 0.001$) and for MPR (RCA: $r = 0.895$, $p < 0.001$; LAD: $r = 0.886$, $p < 0.001$; LCX: $r = 0.886$, $p < 0.001$).

Conclusion: On a global and vessel territorial basis, CMRI-measured absolute myocardial perfusion differences and MPR were strongly and significantly correlated with the Rb-82 PET findings.

1. Introduction

Effectively targeting perfusion abnormalities with interventional therapies requires accurate detection and evaluation of myocardial perfusion defects [1–3]. For absolute quantification of myocardial perfusion, positron emission tomography (PET) is the gold standard. The use of dynamic first-pass cardiac magnetic resonance imaging (CMRI) performed after injection of gadolinium-based contrast agents is not in clinical routine everywhere [4].

The higher spatial resolution of CMRI allows detection of subendocardial infarcts that may be missed by single-photon emission computed tomography (SPECT) [5], which may also be of benefit in perfusion imaging. Furthermore, negative stress CMRI indicates low risk for cardiac death [6]. To date, no study has compared absolute myocardial blood flow measurement using CMRI with that using rubidium-82 PET (Rb-82 PET). Furthermore, a method for absolute CMRI measured quantification of myocardial perfusion has not yet been established for clinical use. The present study aimed to compare global and regional myocardial perfusion measured by CMRI and Rb-82 PET in patients with severe coronary artery disease (CAD).

2. Materials and methods

2.1. Patient population

This study enrolled patients aged 30–80 years, each with at least one significant coronary artery stenosis without collateral vessels visualized on invasive coronary angiography (ICA), and with no options for revascularization [7]. The patients were only included if the ICA was performed within 12 months prior to inclusion. Other inclusion criteria were moderate to severe angina or angina equivalent dyspnea (Canadian Cardiovascular Society class II–IV or New York Heart Association class II–IV) despite optimal medical therapy, and reduced exercise capacity. Patients were excluded if they had any contraindications for CMRI, or creatinine > 130 μmol/L. All included patients gave written informed consent. The study was approved by the National Ethical Committee (02-268856), and complied with the Declaration of Helsinki for Good Clinical Practice.

2.2. Protocol

CMRI and PET were performed on separate days. ECG, blood pressure, heart rate, and clinical condition were monitored throughout the examinations. All patients were instructed to abstain from caffeine-containing products for 24 h and to stop intake of long-acting nitrates for at least 18 h before each examination.

2.3. Cardiac magnetic resonance imaging

Separate power injectors were used to administer the contrast agent and adenosine through 18- and 20-gauge intravenous catheters, respectively, inserted into the left and right antecubital veins. Prior to examination, the patient was placed in a head-first supine position. CMRI was performed with a clinical MAGNETOM Avanto 1.5-Tesla scanner (Siemens, Erlangen, Germany) with a 6-channel cardiac chest coil combined with back surface coils.

After obtaining scout images, short-axis cine images were acquired using an ECG-gated, balanced steady-state free precession gradient-echo sequence with retrospective gating at end-expiratory breath hold, with a scan rate of 25 images per cardiac cycle covering the entire length of the heart.

For rest perfusion, three short-axis slices (basal, mid-ventricular, and apical) were obtained during the first-pass of gadolinium, using an ECG-gated, end-expiratory breath hold, single-shot hybrid gradient-echo saturation recovery TurboFlash sequence (echo-time, 1.14 ms; repetition time, 190.92 ms; flip angle, 12°; field of view, 360 × 360; matrix, 192 × 125 mm; GRAPPA acceleration factor, 2; slice thickness, 8 mm). The gadolinium chelate (Gadovist; Bayer Schering Pharma, Berlin, Germany) was administrated as a bolus of 0.1 mmol/kg body weight at a rate of 5 mL/s, followed by 15 mL of saline at the same rate. One frame (three slices) per cardiac cycle was obtained, with a total of fifty dynamic acquisitions.

Late gadolinium enhancement images were acquired as breath-hold, ECG-gated, inversion recovery fast gradient-echo images, at 10 to 20 min after rest perfusion. The inversion time was set to best null the myocardium (250–380 ms) and images were acquired covering the entire length of the left ventricle.

Stress perfusion images were obtained at least 25 min after the first injection of contrast, with the same settings and image position used for rest perfusion. The stress images were obtained after 2.5 min of adenosine infusion at 140 μg/kg/min, after injecting another bolus of 0.1 mmol/kg gadolinium followed by 15 mL saline. Adenosine infusion was stopped immediately after image acquisition, and the total duration of adenosine infusion was approximately 4 min.

2.4. Positron emission tomography

PET scans were performed using a Siemens Biograph mCT/PET 64-slice scanner (Siemens Medical Solutions, Knoxville, USA). Patients underwent serial rest followed by stress imaging with Rb-82 from a CardioGen-82 Sr-82/Rb-82 generator (Bracco Diagnostics, Inc., Princeton, New Jersey, USA). Standard clinical protocol was used. Briefly, an X-ray scout view over the chest was performed for positioning, followed by low-dose computed tomography (CT) (120 kV; quality reference effective mAs, 11; rotation, 0.5 s; pitch, 1.5; collimation, 16 × 1.2 mm) for attenuation correction of the rest emission data (CTAC). Rb-82 was intravenously infused with a flow rate of 50 mL/min, and list mode 3D data acquisition was started with the tracer infusion continued for 7 min. Static and ECG-gated images were reconstructed with a 2.5 min delay to allow Rb-82 clearance from the blood pool. Stress was induced with adenosine infusion of 140 μg/kg/min for 6 min. After 2.5 min of adenosine infusion, intravenous Rb-82 infusion and list mode acquisition were started following the same protocol as for rest. The patients received in total 1100 MBq 82RbCl for rest and stress images.

Registration between PET and CT images was checked for evidence of patient motion, and manual adjustments were made

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