

A Multimodality Cross-Validation study of Cardiac Perfusion using MR and CT

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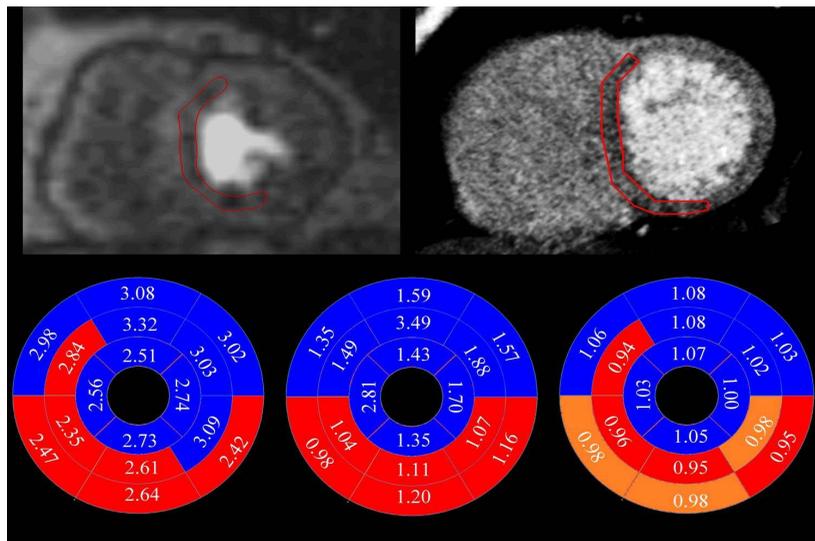
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INTRODUCTION

Magnetic Resonance first pass perfusion (MR-FPP) imaging is as a highly appropriate method for the non-invasive detection of coronary artery disease (CAD) and the assessment of ischemic heart disease¹. Fermi deconvolution modeling applied to cardiac MR-FPP has been demonstrated to provide accurate measurements of myocardial blood flow (MBF) in CAD²⁻³. However, the limitations placed on spatial resolution by the requirements of high temporal resolution and the presence of motion and susceptibility artefacts, mean that absolute quantification of MBF requires further validation. The relatively high spatial resolution of Multi-Detector Computed Tomography (MDCT) makes it a robust method for direct evaluation of stenosis in CAD⁴. Although the latest generation of MDCT scanners is capable of improved spatial resolution and image quality at lower radiation doses, the main limitation to the dynamic investigation of cardiac perfusion with MDCT is still radiation exposure. Stenotic lesions readily identified during routine MDCT coronary artery imaging may therefore only currently be assessed using MDCT "snapshot" perfusion techniques⁴. Variability in heart rate under stress and rest conditions mean that acquisition of snapshot MDCT images at peak contrast infusion at both rest and stress are challenging. Assessment of snapshot MDCT perfusion imaging therefore also requires further validation. Our group has applied a cross-validation perfusion study by comparing absolute MBF values measured using MR-FPP with transmural perfusion ratios (TPR) measured with MDCT in a population of CAD patients. TPR has been shown previously to be lower in patients with CAD⁴. The aim is to use a multimodality assessment of perfusion by using the merits of each technique and establishing a range of comparable cross-validated perfusion assessments.

MATERIALS AND METHODS

MR and CT perfusion data were acquired in a population of 20 consented patients with CAD, and preliminary results are shown here for MBF and TPR in subject 1. A 64 y.o. male with mild to moderate stenosis of the left anterior descending artery was imaged with our combined MR and MDCT protocol. An established stress-rest MR-FPP protocol was implemented for the acquisition of the MR perfusion images using a 3T Verio scanner (Siemens Healthcare, Germany) and 0.025 mmol/kg gadolinium (Gd) (Gadovist, Bayer Healthcare). Left ventricle and myocardium were contoured using validated software (Medis, Netherlands). Segmentation, Gd concentration curve⁵ and Fermi function modeling were performed in Matlab (Mathworks, USA). A linearity relationship between Gd and T1 was calculated by adapting the MR signal equation⁵ and Gd doses through experiments in phantoms (data not shown). A modified Look-Locker Inversion Recovery (MOLLI) protocol⁶ was included to quantify T1 measurements of the myocardium prior to stress and rest perfusion to calculate MBF (ml/g/min). Myocardial perfusion reserve index (MPRI) was calculated, based on the ratio of MBF at stress versus MBF at rest for each myocardial segment. For the CT perfusion images, a 320 MDCT Aquilion One scanner was used (Toshiba Medical Systems, Japan) using iodine contrast enhancement (60*20 Iomeron 400, Bracco). The tube current and voltage were selected automatically, based on the body mass index (BMI) and an ECG-gated snapshot image was acquired at end diastole for stress and rest (4 min post adenosine stress for MR-FPP and MDCT protocols). TPR⁴ was calculated using Vitrea software (Vital Images, USA) and segmentally compared to MBF and MPRI.



RESULTS

MR and MDCT images demonstrated sub-endocardial perfusion abnormality in the septal and infero-lateral regions. In the upper left panel, an MR short-axis perfusion image is shown (red contour outlines the sub-endocardial myocardial perfusion defect reported by two independent, blinded observers (1 cardiologist, 1 radiologist)). In the upper right panel, the corresponding CT short-axis perfusion image is shown with matching perfusion defect in red. MRI-FPP MBF measurements were generated across all segments of three cardiac slices according to a 16 segmentation model (apex was excluded). The bullseye figures present the MBF values at stress (blue: normal, red: abnormal, comparison with healthy volunteers), MPRI values (blue: normal, red: abnormal) and TPR values (blue: normal, orange: mild decrease in TPR, red: moderate decrease in TPR) in lower left, middle and right panel respectively.

MBF and MPRI present a good correlation with TPR with 6 segments showing decreased MBF and MPRI values at stress versus 7 segments showing mild to moderate decreases in TPR. MBF measurements in the apical slice while reduced, were not considered pathophysiological since MBF in the apical slice is generally lower for a cohort of healthy volunteers using this protocol (normal MBF at stress: 3.65 ± 0.75 , normal MPRI: 2.25 ± 0.91).

DISCUSSION-CONCLUSIONS

Patient 1 in our multimodality assessment of CAD perfusion is demonstrated. Further data will be presented, including validation with a subset of CAD patients receiving positron emission tomography-fluorodeoxyglucose (PET-FDG), MDCT and MR-FPP. Absolute quantification of MBF is possible in MR data albeit this is an indirect method to quantify tissue perfusion which is based on the generation of Gd concentration curves in a tissue unit volume through the mathematical calculation of T1 relaxation time at each image during the first pass of contrast through the myocardial tissue. In contrast, CT perfusion imaging is free of susceptibility artifacts which can significantly influence the image quality and MBF measurements in cardiac perfusion MR data. CT perfusion imaging is not dynamic but does benefit from a more direct measurement of contrast agent concentration in a tissue volume by measuring Hounsfield units directly. This cross validation study, not only aims to establish a clinically valuable relationship in perfusion values between MR and MDCT perfusion data but also to surpass critical limitations of the individual imaging methods preparative to gain a better insight of myocardial perfusion in the clinical setting. Accurate spatial correlation of perfusion deficits will be further validated through spatial registration of our MRI, MDCT and PET-FDG datasets, which we are currently investigating.

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