Fully Quantitative Perfusion Pixel Maps of First-Pass Contrast-Enhanced MRI for Coronary Artery Disease Detection: A Preliminary Evaluation in Patients

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Introduction:

First-pass contrast-enhanced MR perfusion imaging can detect obstructive coronary artery disease (CAD) [1]. The interpretation of the perfusion imaging is typically performed by experienced readers in qualitative assessment of the images or by analysis of myocardial time-signal intensity curves. While the later adds objectivity to the diagnosis and may improve the accuracy, it is often hampered by the time-consuming process of manually defining the myocardial regions of interest and by a downgraded resolution of a sector based analysis. In this study we aim to evaluate an automated image analysis method for myocardial perfusion quantification. Combining an automated non-rigid image registration and fully quantitative pixel-wise analysis of perfusion images, we assess the performance of this automated method for detecting CAD in patients.

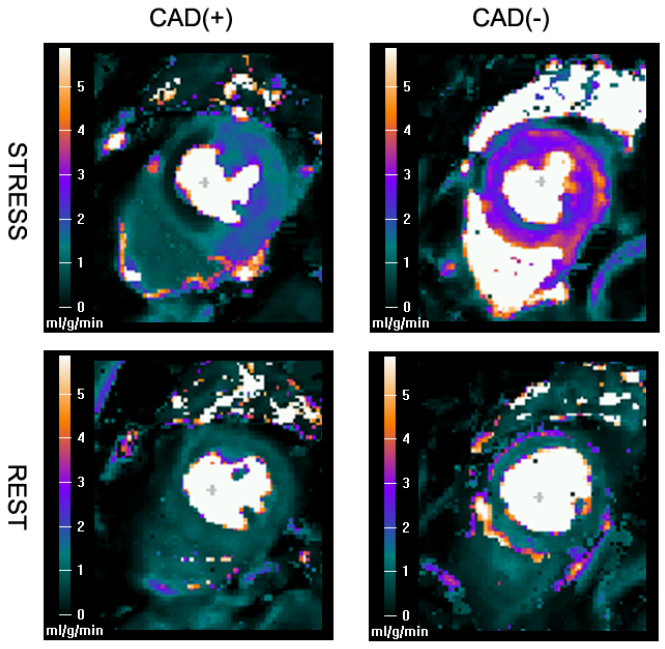
Materials and Methods:

Twenty patients with known or suspected coronary artery disease were included in this study. All subjects had coronary catheterization or computed tomography angiography within 90 days of the MRI. Both dipyridamole stress (0.56 mg/kg) and rest perfusion MR imaging were performed on every patient. Aminophylline was administered after the stress study to minimize the residual effects of vasodilation before rest imaging. The MR imaging was performed with a 1.5 T scanner (MAGNETOM Avanto or Espree, Siemens Healthcare, Erlangen, Germany) using a steady-state free precession (SSFP) dual-sequence method [2] with saturation recovery magnetization preparation. A Gd-DTPA contrast bolus at 0.05 mmol/kg was injected at 5 mL/sec for first pass perfusion imaging. The dual-sequence method obtains a low-resolution atrial input function (AIF) image and higher-resolution myocardial images (typically 3 slices per RR). Typical imaging parameters included a non slice-selective composite 90° saturation preparation pulse, 50° read out, SR time 90 ms, TE/TR 1.2/2.4 ms, FOV 360x270 mm, acquisition matrix 128x80, slice thickness 8 mm, and TGRAPPA parallel imaging R=2. The low resolution AIF image was acquired with FLASH sequence (64x48, TE=0.7 ms, acquisition matrix 64 x 48). For each perfusion acquisition, an AIF image plus three myocardial slices per RR were collected for 60 heartbeats. At the beginning of each scan, two proton density weighted images were also acquired to correct for surface coil related image inhomogeneity.

An automated on-line non-rigid image registration method [3] was used to align myocardial perfusion images. This was implemented within the Siemens Image Calculation Environment (ICE), the scanner automatically generated motion compensation (MOCO) myocardial perfusion images after the original perfusion images were reconstructed. The MOCO myocardial images and the original AIF images were then used to compute fully quantitative myocardial perfusion flow (MBF) estimates through a model constrained deconvolution technique [4] by a custom software written in Interactive Data Language (IDL). The arterial input function was automatically extracted from the images using difference images of the AIF image series. A fully quantitative perfusion MBF map was generated on a pixel-by-pixel basis at each slice location for the entire image without manual tracing of myocardial regions of interest such as endocardial and epicardial borders in all images. Fully quantitative color MBF maps of both MR stress and rest perfusion studies were generated based on a calibrated color scale and compared with clinical MR image interpretation. The results of MR findings were compared against the reference standard of invasive cardiac catheterization (CATH) or computed tomography angiography (CTA) percent stenosis. Clinical interpretations of the MR exam were performed by 2 experienced readers based on qualitative assessment of the perfusion images as well as time-signal intensity curves of the images using a 16 segment model. Patients were categorized as CAD+ and CAD− groups; CAD+ is defined as a >70% stenosis in at least one major artery, and CAD− is defined as no significant coronary obstruction.

Results:

The average age of the patients was 58 years (range from 39 to 80) and 16 were men. Eight patients were CAD+ and 12 were CAD−. 7 patients had 1-vessel coronary stenosis and 1 had 2-vessel stenoses. Figure-1 shows examples of the pixel-wise perfusion MBF maps in both CAD+ and CAD− patients. The CAD− patient shows high global myocardial flow estimates in the stress pixel map. In the stress perfusion pixel map of the CAD+ patient, there is a severe anteroseptal perfusion defect which is depicted as low MBF in a dark-green to black color corresponding to a 99% stenosis in the LAD. For the group results overall, fully quantitative stress perfusion pixel map showed obvious defects in 7 of the 8 CAD+ patients. The majority of these patients had lower subendocardial blood flow during stress than at rest. The one false negative case had residual motion related artifacts on the stress MOCO perfusion images. In the 12 CAD− patients, quantitative perfusion pixel maps in general showed higher MBF estimates at stress circumferentially than in the CAD+ patients. All but one CAD+ patient had relatively uniform transmural flow but there were patchy regions of high flow near epicardium in 4 patients that may be related to residual motion artifacts.



Discussion:

Overall the results of this exploratory study are encouraging. We show that fully quantitative perfusion MBF pixel maps can be generated in an automated fashion. We also show that high-resolution perfusion MBF pixel maps can detect significant coronary stenosis in patients with known or suspected coronary artery disease. Based on the stress perfusion images only, the performance of the MBF maps is close to expert clinical interpretation. Considering the amount of manual labor needed to analyze perfusion images, this study shows a major advance in the feasibility of quantitative perfusion imaging for coronary artery disease detection at a pixel level.

References:

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