Myocardial Perfusion Reserve Index Imaging
Via First-Pass Gd Dynamics in Vasodilated and Rest Conditions

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Purpose
This project aims to demonstrate the feasibility of practical multislice semiquantitative myocardial perfusion reserve (MPR) imaging of the LV myocardium at the native resolution of the MR image acquisition for the work-up of ischemic heart disease.

Introduction
Myocardial perfusion reserve quantifies the capacity of the circulatory response to a maximal increase in metabolic demand. MPR indicates the net circulatory consequence from coronary lesions and other vascular states, regardless of their morphological appearance, including the compensation by collateral flow. Myocardial collaterals readily develop in response to ischemia induced by upstream stenosis or occlusion. In canine model, Aomedi constricators will induce new coronary collaterals providing perfusion of ~35% of maximal normal blood flow in ~95% of dogs. Recent improvements in perfusion acquisition methods now provide increased temporal and spatial resolution, SNR, and first-pass contrast enhancement ratios. Semiquantitative MPR can be achieved with MR methods using current USFDA-approved contrast agents.

Methods
High-speed multislice MR images were acquired during the first pass of Gd-contrast antecubital-vein injection (0.1 mmol/kg, 5 ml/sec) in both adenosine vasodilated ‘stress’, and ‘rest’ states. Stress and rest dynamic image sequences for 7 short-axis slice locations spanning the LV were post processed to calculate the estimated MPR image for each slice location (custom software written in IDL). The computation procedure applied for each slice location:

1. Register each individual time series at each slice location to compensate for diaphragm motion and cardiac phase jitter
2. Determine a surface coil intensity correction
3. Calculate first-pass upslope parametric images
4. Segment the LV blood pool based on time-to-half-maximum parameter
5. Perform warping image registration of rest slope image onto stress slope image
6. Calculate the MPR index image by:

\[
MPR(x,y) = \left( \frac{\text{S_{LVBP}.stress}(x,y)}{\text{S_{LVBP}.rest}(x,y)} \right) \times \left( \frac{\text{S_{MYO}.stress}(x,y)}{\text{S_{MYO}.rest}(x,y)} \right)
\]

where \text{S_{LVBP}.stress} is the computed first-pass upslope at pixel (x,y), and \text{S_{LVBP}.rest} is the upslope of LV blood pool pixel function for normalization.

Results
The figure shows the resulting MPR index image for patient having an 80% right coronary artery stenosis. MPR index values within normal myocardium range from 1.0–2.5, about half the expected MPR. MPR index values within perfusion defects range from 0.0–1.0. Distributions of normal and abnormal myocardium MPR values are well separated suggesting that this simple index approach may be useful for clinical discrimination.

Discussion
Three morphological issues challenge the computation of MPR parametric images: (1) Cardiac phase shifts between the stress and rest acquisitions arise from the difference in heart rate during the two test states. These phase shifts necessitate a warping image registration. Since myocardial anatomy mismatches, this may pose the ultimate limitation of the method. (2) Stress-rest difference in diaphragm positions cause mismatch in ventricular anatomy that must be compensated via warping image registration. (3) Cardiac phase jitter within a given slice location image sequence results in variable partial volume averaging of the myocardial edge voxels, which introduces variability over time in LV edge features.

The feasibility of high-resolution practical MPR index images has been demonstrated. MPR imaging may provide quantitative objective information to aid the interpretation and documentation of MR myocardial perfusion exams.

References

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