Correction of Myocardial Perfusion Reserve Data from First-Pass MR Imaging at 3.0 Tesla with Parallel Imaging

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PURPOSE: Clinical three Tesla (3T) MRI systems are now available that promise increased signal over 1.5 T systems. Furthermore, parallel imaging with phased-array coils should allow increases of imaging speed. However concerns have been raised that cardiac images at 3T will produce major image nonuniformities from two sources; the coil sensitivity profile and radio frequency absorption at 128 MHz (1). The purpose of this study is to evaluate image nonuniformities for 3T MRI first-pass contrast-enhanced myocardial perfusion imaging, develop a method for compensating for these artifacts and evaluate their influence on the myocardial perfusion reserve index (MPRI) in normal subjects.

MATERIALS AND METHODS: Fourteen healthy volunteers (mean age=49.29 years) were assessed with MR first-pass myocardial perfusion imaging using a 3T MRI system (MAGNETOM Trio, Siemens Medical Solutions) with an 8-channel cardiac phased array RF coil. For each subject two CMRI perfusion data sets were collected under normal resting conditions and pharmacological stress using a saturation recovery steady-state free precession (SR-TrueFISP) sequence combined with parallel imaging using GRAPPA with an acceleration factor of two. For the first perfusion scan, after six minutes of adenosine infusion (Fujisawa 140 μg/kg/min) a dose of a contrast agent (0.03mmol/kg Gd-DTPA) was injected. Four slices with 40 short axis image frames per slice were acquired during and immediately following the Gd injection with ECG triggering and breath-holding. Twenty minutes following cessation of adenosine infusion, a repeated dynamic perfusion scan was performed with gadolinium but without adenosine infusion to produce data for the resting condition. All the imaging parameters, TR = 170ms, τ = 100ms, TE = 0.93ms, flip angle = 30°-50°, matrix size =144×192 and the slice thickness = 8mm were kept the same for both perfusion scans. In between the perfusion scans LV functional data were acquired using a segmented TurboFLASH cine (TE= 1.34 ms; TR=41.44 ms, flip 37°) acquisition with the same FOV, slice thickness, slice positions and GRAPPA as used for the perfusion imaging. Typically 10 cine phases were acquired in a breath-hold less than 20 s.

Perfusion data were analyzed by dividing the basal, midbasal, and midapical slices into 6 segments and the apical view into 4 segments (total of 22 segments). Prior to the upslope calculations, a nonuniformity correction was applied to reduce the SI nonuniformities over different myocardial segments. First, images that were acquired from the cine study at the same cardiac phases and slice positions as the perfusion images were selected. The ROI from the cine acquisition was measured (SI_{cine}) and the normalized SI (SI_{norm}) for each segment was calculated by: $SI_{norm}= SI_{orig}/ SI_{cine}$. Then, the corrected signal for each segment, SI_{corr} was calculated by subtraction of the averaged baseline signal, SI_{base} from SI_{norm}: $SI_{corr}= SI_{norm}-SI_{base}$. Upslope indexes for both rest and stress data series were derived separately from the normalized slope using a Fermi curve fitting model. MPRI was calculated by dividing the upslope at stress over the upslope at rest. MPRI and upslope data were analyzed separately using a one-way ANOVA with segment number as the independent variable. A *p* value <0.05 was considered statistically significant.

RESULTS: The average MPRI is 2.46±0.16, which is comparable to the cardiac magnetic resonance (CMR) results previously obtained from 1.5T scanners. (2) The nonuniformity correction method successfully reduced the differences in upslope between myocardial segments (Fig. 1) to nonsignificant levels (Fig.2). After nonuniformity corrections were applied, no significant differences in MPRI between myocardial segments were found (p=0.86). MPRI results measured from different slice positions also produced no significant difference (p=0.85) (Fig.3).

CONCLUSION: Myocardial perfusion reserve imaging at 3T provides superior SNR, spatial and temporal resolution over 1.5 T. In spite of image nonuniformities MPRI allows for a reliable assessment of myocardial perfusion compared with the assessment of the upslope at stress or at rest only since the calculation of a perfusion reserve itself normalizes for position dependent signal intensity differences within the image. Although the proposed uniformity correction method did not significantly change the MPRI measurements, it does appear to be effective and may prove useful for more quantitative perfusion studies at 3T.

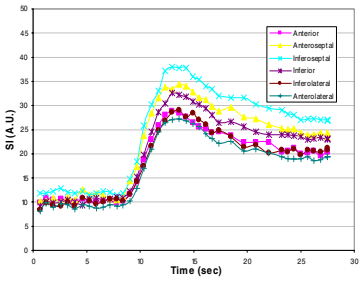

Figure 1. Representative SI(t) curves for each segment before correction.

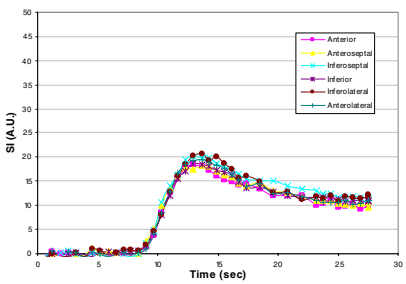

Figure 2. Uniformity correction reduces variability in SI(t) curves from Fig.1

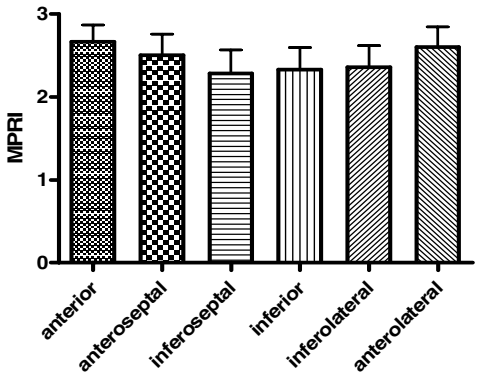

Figure 3. Mean MPRI from 14 subjects after uniformity corrections (error bars = SD) were not significantly different from uncorrected values.

REFERENCES:

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