Systolic 3D first-pass myocardial perfusion MRI

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Introduction: First-pass myocardial perfusion imaging (MPI) is now an established tool for the assessment of ischemic heart disease, and the most widely used protocols involve 2D multi-slice acquisition. Three-dimensional (3D) MPI is potentially advantageous due to its contiguous spatial coverage and high SNR [1], and has been recently shown to be more accurate than 2D multi-slice techniques in sizing defects [2]. Typically, 3D data acquisition is temporally positioned at the center of diastole when the heart is the most stationary. End-systole is the second longest quiescent cardiac phase, and may be advantageous, due to its reduced sensitivity to R-R variability and arrhythmia [3,4]. Also, low in-plane spatial resolution may be well-tolerated in systolic images due to thicker myocardium. The main goal of this study was to investigate the feasibility of systolic 3D MPI and compare image quality and time intensity curves with diastolic 3D MPI. We performed this comparison in healthy volunteers.

Methods: The pulse sequence consisted of two saturation recovery 3DFT GRE acquisition modules, one at end-systole and the other at mid-diastole. The centers of the two acquisition windows were manually pre-determined using scout CINE images. In both acquisitions, three-dimensional k-space was undersampled by factor of three and two along ky and kz directions, respectively, and was reconstructed using TSENSE [5,6]. The imaging parameters for systolic/ diastolic acquisitions were: TR=2.1/ 2.3 ms, matrix size= 62×42×8/ 100×66×10, FOV 28×28×8/ 28×28×10 cm^2, acquisition time= 144.8/ 304.7 ms, flip angle= 12/ 12º. Saturation recovery time T_{SR} was limited by an R-R duration available, and the pulse sequence used the longest T_{SR} possible with a maximum value of 120 ms. In-vivo dual 3D MPI was performed in three healthy volunteers using a GE 3T scanner and an eight-channel cardiac receiver coil. Contrast agent (0.05 mmol/kg Gd-DTPA) was injected at a rate of 4 ml/s at the start of scan. Perfusion images were normalized by the temporal average of the first five pre-contrast images, and were divided into six (basal and mid-short axis levels) or four (apical level) segments to generate time intensity curves (TIC).

Results: Both diastolic and systolic images clearly show the arrival and the passage of contrast agent with high signal-to-noise ratio (Fig. 1). Systolic images suffer slightly from blurring and ringing artifacts due to the low spatial resolution. Fig. 2 shows examples of TICs of diastolic and systolic images which are closely located at the mid short axis level (dotted boxes in Fig. 1). All six segments show uniform enhancement in each of the two plots, and the upslope of the systolic TICs is comparable to diastolic one. Fig. 3 shows the mean and standard deviation of TIC upslopes across all myocardial segments per subject. The TIC upslopes vary over subjects due to the variations in heart rate and the corresponding T_{SR}, but the difference between diastolic and systolic upslopes is negligible.

Discussion: We have demonstrated the feasibility of systolic 3D MPI, by performing dual 3D MPI in healthy volunteers. Perfusion images of diagnostic quality were obtained from both mid-diastole and end-systole. The TIC analysis has shown that signal enhancement in systolic perfusion images is equivalent to that of diastolic images. Spatial resolution of systolic images may be insufficient for the depiction of the extent of sub-endocardial defects, and the use of higher acceleration techniques is under investigation. The comparison of diastolic and systolic 3D MPI will be performed in patients with ischemic disease.

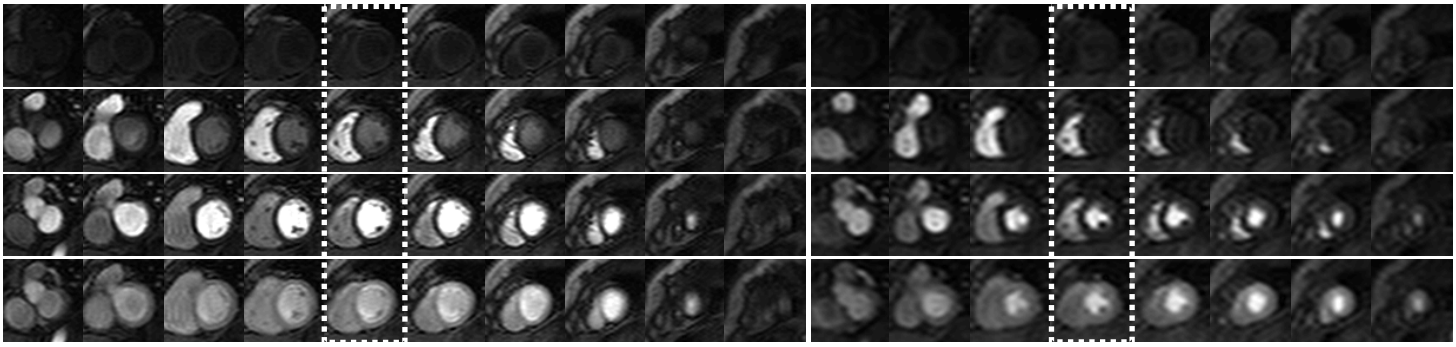

Figure 1. Representative 3D perfusion images from mid-diastole (left) and end-systole (right). The four rows represent pre-contrast, RV enhancement, LV enhancement, and myocardial enhancement from the base to apex.

References:

[1] Kellman P et al. ISMRM2004: 310.
[2] Shin T et al. submitted to JCMR.
[3] Weissler AM et al. Circ 1968; 37: 149-159.
[4] Cieslinski A et al. Br Heart J 1984; 51: 431-437.
[5] Kellman P et al. MRM 2001; 45: 846-852.
[6] Weiger M et al. Magma 2002; 14: 10-19.

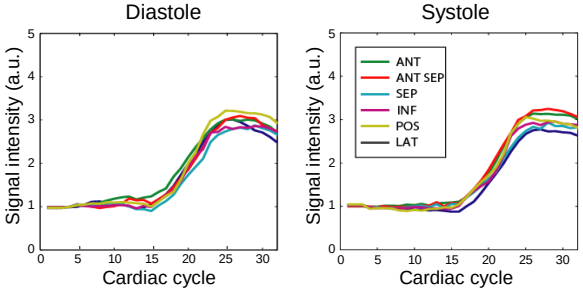

Figure 2. Representative time intensity curves in Subject #3.

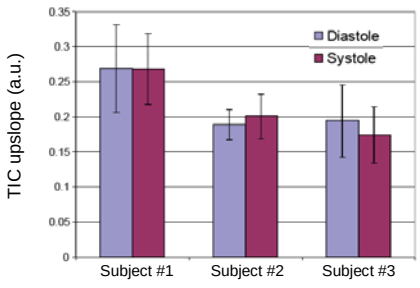

Figure 3. Mean and standard deviation of TIC upslopes across all myocardial segments