Quantification of myocardial perfusion with an undersampled radial acquisition

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INTRODUCTION Myocardial perfusion magnetic resonance imaging is emerging as a useful modality to assess myocardial ischemia, although there remain challenges related to artifacts, coverage, and quantitation. Recently a rapid undersampled radial k-space perfusion sequence was shown to have promise for qualitative perfusion imaging and offers reduced artifacts and increased coverage compared to most other current methods [1]. Quantitative analysis of blood flow estimates using this myocardial perfusion sequence is investigated here.

METHODS MRI experiments were performed on a 3T MRI system (Trio, Siemens Healthcare), using spine and body phased array coils. One volunteer was given a relatively low dose of 0.03 mmol/kg Gd-BOPTA twice, once with a radial acquisition and once with a Cartesian acquisition. Another volunteer was given a higher dose of 0.06 mmol/kg (Gd-BOPTA) twice and scanned in the same way. The Cartesian acquisitions used a turbo-FLASH sequence with saturation recovery, TR/TE ~2/1 ms, saturation recovery time (SRT) 115 ms, flip angle=18 ^{o}, with TGRAPPA, R=2 and slice thickness 8 mm.

For the radial sequence, a saturation pulse was used only once for every five slices, and only 24 projections were acquired for each image. Every set of 24 projections was acquired as four interleaved subsets of 6 projections each. Imaging parameters were similar to the Cartesian case, although SRT varies with slice and the field of view was somewhat smaller. The radial k-space data was reconstructed with the spatiotemporal constrained reconstruction (STCR) method [1]. This method also fits in the more recent compressed sensing framework.

The Cartesian and radial images were processed in similar ways. Respiratory motion across the time frames was corrected and arterial input function (AIF) was obtained from the left ventricular blood pool. Myocardium for each slice was divided into six equiangular regions and the mean tissue enhancement curves were obtained. A special procedure was used to obtain unsaturated AIFs from the radial images. It has been reported that normalized tissue curves of slices with different effective SRT (eSRT) are almost identical, although the AIF with long eSRT can be underestimated for the radial method [2]. For correction of the underestimated AIF, we used the AIF with the shortest eSRT (slice 1 or 6). Preliminary results implied that the AIF was still somewhat saturated at the doses used. In order to provide a larger linear range for gadolinium (Gd) concentrations, the SRT of the first slice was effectively shortened by using only the first subset of 6 projections for the center portion of k-space when the peak portion of the AIF was calculated. The peak portion was scaled to match the initial onset of contrast and the tail of the AIF that were computed with reconstructions using all of the 24 rays since those areas were within a linear range. The curves were then fit using a two compartment model to give K^{trans} estimates.

RESULTS In Fig 1, one time frame of the first 5 slice images with different eSRTs illustrates the type of images obtained with the undersampled radial method. In addition, K^{trans} =0.78±0.13 for the low Gd concentration subject using the radial method (1.08±0.20 using Cartesian), which implies that this method can correct the underestimation of the AIF. Furthermore, the radial method gave more reasonable K^{trans} estimates for the high dose of Gd. It corrected 1.28±0.17 with Cartesian to 0.79±0.18 with radial method. The corrected AIFs are presented in Fig 2, showing that the AIF of the high Gd concentration subject needs more correction than the lower dose subject. All slices are scaled to match the baseline after the first pass. Although not shown, tissue enhancement curves for the Cartesian and radial acquisition are similar.

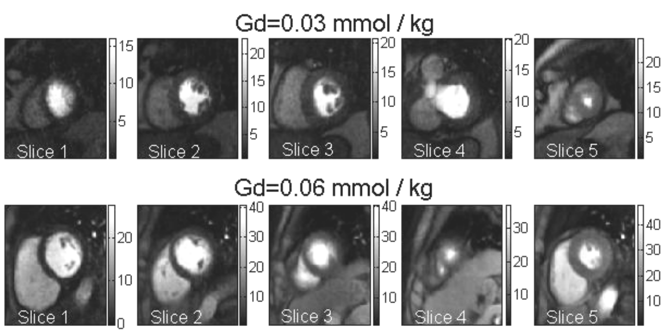

Fig. 1. Images of the first five slices with the low and high dose volunteers, reconstructed from undersampled radial acquisitions. The eSRT increases from left to right (approximately 36, 108, 180, 252 and 324 msec)

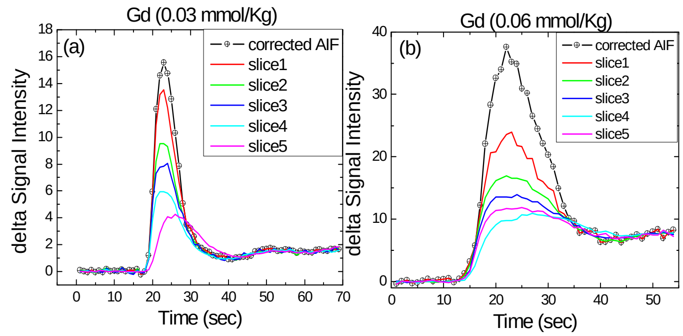

Fig. 2. *AIFs of the first five slices from the radial acquisition. The "corrected AIF" is from slice 1 reconstructed with a reduced eSRT, as described in the methods section.*

DISCUSSION and CONCLUSIONS In this report, we present perfusion results of *in vivo* cardiac MRI using radial and Cartesian measurement techniques. The new undersampled radial imaging method, which offers some control over the effective saturation recovery time, can provide more reasonable K^{trans} estimates over a range of doses as compared with a more conventional Cartesian method.

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