Investigating Myocardial Field Distortions During First Pass of a Gadolinium Based Contrast Agent in Perfusion Studies

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Aim

In this work a method has been developed and used to measure the field distortions caused by the first pass of a Contrast Agent (CA) in a typical perfusion setup, and determine how these distortions may depend on cardiac long-axis orientation.

Introduction

Myocardial Perfusion (MP) studies using MRI have recently improved in terms of resolution and coverage, providing a valuable contribution to the detection of Coronary Artery Disease (CAD). However, MP images are often affected by artifacts, most commonly the Dark Rim Artifact (DRA), which appears in the subendocardium during the first left-ventricular pass of the CA mimicking an under-perfused region.
The exact origins of the DRA are unclear and several causes have been suggested: motion [1]; Gibbs truncation [2]; non-uniform k-space weighting [3]; and susceptibility associated with CA concentration [4-6].

Methods

Gadolinium (Gd) contrast agent (Magnevist-Schering, Germany), with a dose of 0.1 mmol/kg of body weight was injected at 5 mL/s in 10 patients (average age 45). Field plots were acquired in three short-axis slices, during the first pass of CA with the patients holding their breath for as long as comfortably possible during 40 R-R intervals. The slice order was always apical, mid, and basal. The study was performed using a 1.5T scanner (Avanto; Siemens) with anterior/posterior phased array cardiac coils. A FLASH sequence was used with magnitude and phase reconstructions: TR/TE of 256/2.48ms; base resolution 192 pixels; pixel size 1.8x1.8x10mm to 2.2x2.2x10mm; flip angle 12 degrees; bandwidth 744 Hz/pixel; GRAPPA, R=1.7. The coil images were saved separately, and phase correction was disabled in image reconstruction.
Single-shot frequency-offset maps were calculated using Matlab where the phase image of each coil for the first frame (before CA) was subtracted from each subsequent frame's corresponding phase images, before magnitude-weighted phase combination. The first frame was chosen to be that before contrast arrival to the right ventricle but with the patient at a stable breath-hold position. Four Regions Of Interest (ROIs) were drawn in the subendocardium (septal, posterior, lateral, anterior) for each slice, and frequency offsets as a function of time were extracted, measuring also the peak field distortion of each ROI during the contrast agent first pass. The *in-vivo* measurements were compared with numerical simulations and specially constructed phantoms that mimicked the LV chamber and myocardium, assuming 1% to 1.5% (1% = 5mmol/L) of Gd-DTPA concentration in the LV.

Results and Discussion

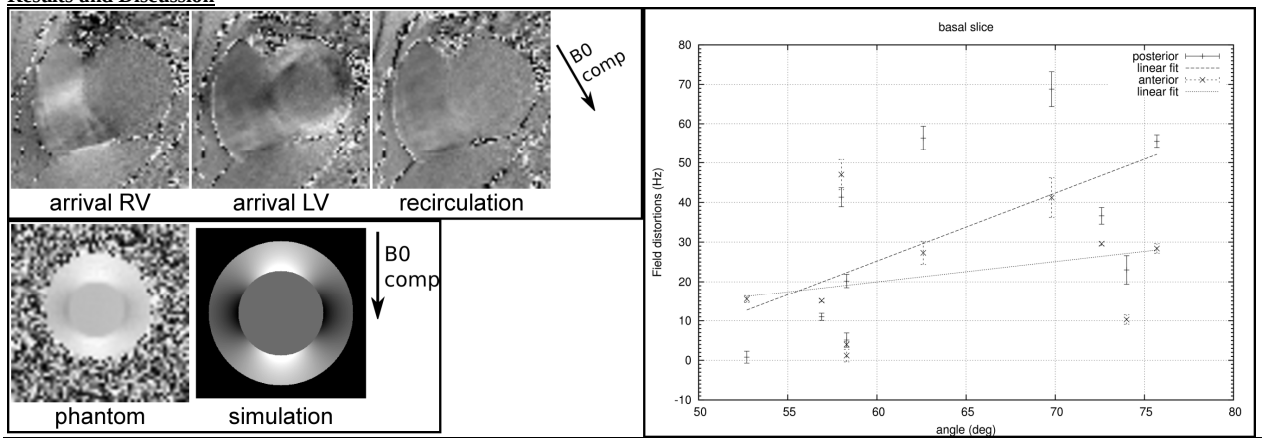

Figure 1: Left top: Field distortions for the first pass of Gd-DTPA in the heart for one of the patients in the basal slice. From left to right we have the first pass of contrast agent in the right ventricle, the left ventricle and during recirculation. During the first pass in the LV, all patients showed an increase of B0 in the posterior and anterior myocardial segments (brighter regions) and a decrease of B0 in the septal and lateral segments (darker regions). The in plane component of B0 is shown. Left bottom: Cylindrical phantom and a numerical simulation of the LV blood pool and myocardium, with the same angle between the long axis and B0 as the patient on the left (i.e. = 70 degrees). The arrow represents the in-plane component of the main field. Right: Field distortion vs. angle for each patient in the basal slice for the posterior and anterior ROI.

First-pass contrast agent in the LV distorts B0 mainly in the myocardium but also in the LV blood pool (Figure 1: left top). The distortion tends to increase when the heart long axis is more across B0 (Figure 1: right). The *in-vivo* measurements showed the same pattern, and similar frequency offsets when compared to both numerical simulations and the phantom (Figure 1: left bottom). The field distortion measured in this study resulted in a maximum frequency shift of 70 Hz in the subendocardial region coupled with a -20 Hz shift in the LV blood-pool. If we consider a perfusion sequence with a TE of 1ms, this would cause an intra-voxel phase range of approximately 0.57 radians between the subendocardium and the blood-pool. Assuming a worst-case 50% partial volume with the LV, the voxel's total signal would be reduced by approximately 10 % only. The levels of field distortion obtained in both the phantom and numerical simulations agree well with the patient's data so as the increasing distortions as the angle increases.

Conclusion

During the first-pass, B0 distortion occurs mainly in the subendocardium, and the same pattern is observed for every patient (anterior/posterior positive; septal/lateral negative). The myocardial B0 distortion is larger in patients with a more "horizontal" heart, i.e. when the long axis of the heart is across the field. From these results it appears that the field distortions are too weak to cause DRAs due to intravoxel dephasing.

References

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