Prospective motion correction for intra-cardiac 3D delayed enhancement MRI using an MR-Tracking Tetrahedron

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Introduction

Myocardial Delayed Enhancement (MDE) MR imaging has been used for visualization of myocardial scar tissue created due to radio-frequency ablation (RFA) of the left atrium for the treatment of atrial fibrillation [1,2]. After administration of gadolinium-DTPA contrast, ECG-gated 3D-MDE is performed with an inversion-recovery preparatory pulse, followed by a segmented k-space gradient-echo (GRE) acquisition, which requires >10 minutes to acquire an image of sufficient resolution to discriminate ablation gaps. Prior work showed an intra-cardiac MR coil offers 8-10 times higher signal-to-noise ratio (SNR) than surface cardiac-arrays, allowing acquisition of high-resolution images in shorter scan times [3]. However, since intra-cardiac coils move with the anatomy, motion artifacts are more severe. Integrating MR tracking coils and intra-cavitary coils, combined with prospective motion correction, has demonstrated improved image quality in 2D-GRE [4]. In this study, we propose to extend prospective motion correction techniques using MR tracking coils to 3D-MDE imaging.

Methods

Four tracking coils were mounted on an expandable intra-cardiac imaging catheter, which when expanded, assumed a tetrahedral shape [4]. Each of the 4 coils was connected to an individual receiver channel, allowing simultaneous motion detection. Readouts in three orthogonal axes detected 3-D translational and rotational motion. Phase dithering [5] was used to eliminate background signal coupled from the adjacent imaging coil. A 3D-MDE sequence was modified, adding 2 tracking segments in each RR, one before and one after the imaging segment (Fig.1). At the start of the scan, the position of the tracking coils was set to be the baseline. During imaging, the position detected by the first tracking segment in each RR was compared with the baseline. When the detected motion was bigger than a preset threshold (1 mm), the acquired imaging data was rejected and the 2nd tracking segment was omitted. This process assured the same volume was imaged during the entire scan. If data was rejected too many (>16) times continuously, a dynamic baseline update was implemented using the mean of the prior 16 positions, which accommodated gradual baseline changes. The motion detected from the 2nd tracking segment was compared with the 1st segment. If the difference was bigger than a threshold, the previously acquired data was also rejected, since it was assumed to be contaminated with motion which occurred during acquisition. Experiments were performed on a GE (Milwaukee, WI) 1.5T. An ex-vivo swine heart was imaged using the modified sequence with the table cyclically displaced by 10mm in the Superior/Inferior direction, interspersed by motionless periods. A 5" imaging coil was used with tetrahedron tracking array.

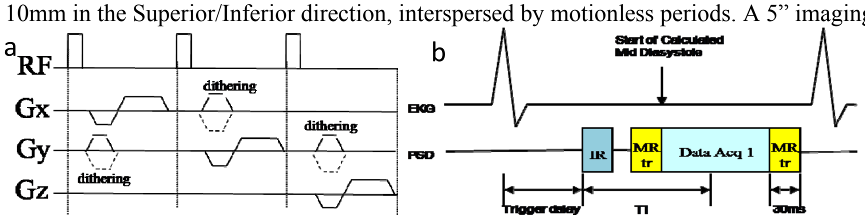
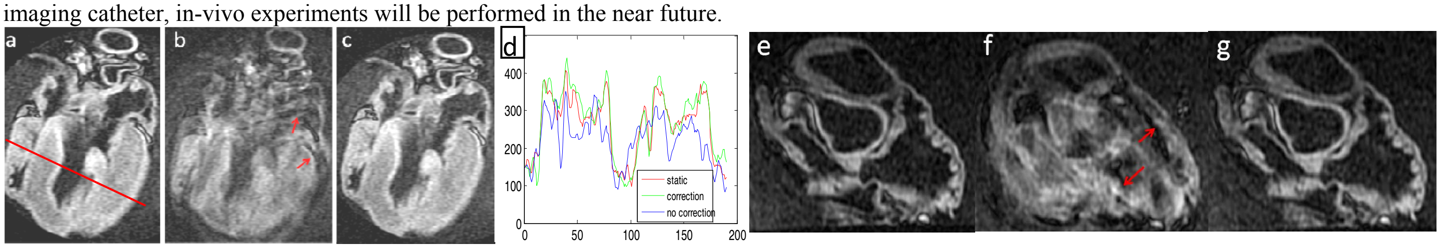


Figure 1. (a) MR-Tracking sequence. Profiles along 3 axes detect 3D coil location and orientation. (b) Modified 3D-MDE with integrated MR-tracking subsequence. Acquisition was performed in mid-diastole. Two tracking segments (MR tr) were added, before and after the imaging segment, and used to determine motion-less physiological periods, and acceptance or rejection of acquired data.

Results and Conclusion

Fig. 2 shows in-plane (a-c) and through-plane (e-g) motion with static, moving w/o correction, and moving with correction images. (d) shows profiles extracted from (a-c) across the left ventricle (red line in a). The corrected case preserves nicely shape and edges, while the uncorrected case does not. The correlation between corrected and static profiles is 0.96, vs. only 0.74 between the uncorrected and static. Similar improvement can be found in (e-g), with motion correction preserving structural details in the left atrium. *Conclusions*: Prospective motion correction using MR tracking dramatically improves image quality for 3D-MDE, even when severe motion occurs. Using integrated tetrahedron tracking coils on an intra-cardiac imaging catheter, in-vivo experiments will be performed in the near future.



***3DMDE**:TR/TE/TI/FA=4/2/420ms/25^o,[TI that nulled blood signal]**,** 32 Views/RR,BW=$\pm$32KHz,FOV = 18cm, Resolution: 0.7*0.7*2.4mm^3. **Tracking**: TR/TE/FA=7.5/3ms/5^0,FOV=30 cm, BW=$\pm$16 KHz, Resolution: 1.2x1.2x1.2mm^3 ,rejection threshold >1.0mm*

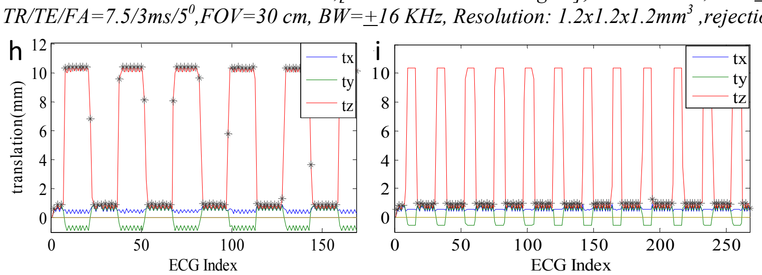


***Figure 2.** Prospective motion correction in a moving ex-vivo swine heart using tetrahedral-based tracking. (a-c) In-plane motion correction, left: stationary image; middle: moving without correction; right: moving with correction; red arrows highlight motion artifacts. (d) is the profile across the red line in (a) from the 3 images. (e-g) Through-plane motion correction. (h-i) Motional pattern detected with the tracking coils. tx, ty,tz denotes motion in the respective directions, and '*' marks accepted positions. Non-corrected case (h), is where all points are accepted, while corrected case, (i) is where only points close to the baseline are accepted.*

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References: [1] Reddy, J Cardiovasc Electrophysiol (2008), [2] Schmidt, Circ. Arrythmia. EP. 2009, [3] Schmidt , *AHA scientific sessions* and *Circulation* 2004 [4] Qin, ISMRM, 2010. [5] Dumoulin, ISMRM 2010.