FREE-BREATHING 3D LATE GADOLINIUM ENHANCEMENT MRI USING OUTER VOLUME SUPPRESSED PROJECTION NAVIGATORS

Rajiv G Menon[1], G Wilson Miller[2], Jean Jeudy[1], Sanjay Rajagopalan[3], and Taehoon Shin[1]
[1]*Diagnostic Radiology and Nuclear Medicine, University of Maryland, Baltimore, Baltimore, MD, United States,* [2]*Department of Radiology and Medical Imaging, University of Virginia, Charlottesville, Virginia, United States,* [3]*Division of Cardiovascular Medicine, University of Maryland, Baltimore, Baltimore, MD, United States*

TARGET AUDIENCE: MR engineers, physicists, and clinicians interested in late gadolinium enhancement (LGE) Imaging

PURPOSE: LGE MRI has become the method of choice for assessment of myocardial viability due to its excellent scar contrast and high spatial resolution [1,2]. While the standard protocol uses 2D multi-slice acquisitions during breath-holds, isotropic 3D free-breathing imaging will be beneficial for improved scar delineation without limitations in orthopneic patients [3]. The purpose of this study was to develop a respiratory motion-corrected 3D LGE MRI technique and to demonstrate its feasibility in cardiac patients.

METHODS: The proposed 3D LGE sequence consisted of an adiabatic inversion pulse (INV), an inversion delay, a fat saturation pulse (Fat SAT), outer volume suppression (OVS) magnetization preparation pulse, 1D projection based 3D motion navigator (NAV) followed by a 3D stack-of-spirals acquisition (Figure 1). The suppression of the volume outside the heart by OVS preparation allows for reduced imaging field of view (FOV) for scan acceleration and more importantly, increases the accuracy of motion estimation by isolating the heart in the projection images. The OVS preparation pulse was implemented by an adiabatic 90° tip-down followed by a spiral 2D selective tip-up with a circular passband of diameter=12 cm [4]. 1D projection images along 3 dimensions were acquired by traversing the 3 k-space axes (Figs. 2a and 2b). 3D motion can be estimated through iterative search for the maximal correlation between two projection images to be registered, and can be corrected for by applying appropriate linear phase in k-space. For accelerated data acquisition, dual density spiral design was used with 2-fold undersampling in the outer region beyond 20% of the k-space radius.

The proposed motion correction was tested in a phantom located at 3 different positions during the scan (Fig. 2c). Free-breathing 3D LGE was performed in 5 cardiac patients who were undergoing clinically ordered MR examinations including the standard LGE imaging. The imaging parameters for both phantom and in-vivo testing included spatial resolution = 1.6x1.6x2 mm^3, FOV = 30x30x16 cm^3, repetition time = 2RR intervals, view per spiral segment = 8, acquisition window = 97 ms. The total scan time was 100 heartbeats (3 min 20 sec based on 60 beats/min). The 3D LGE scan was started immediately after the conventional 2D multi-slice LGE, approximately 20 min after the administration of contrast media (0.2 mmol/kg, MultiHance).

RESULTS: Figs. 2d and 2e contains the result of phantom testing, demonstrating successful motion estimation and correction. All the 5 patients were diagnosed to have no scar evidenced by both the 3D and 2D LGE images. Figure 3 shows representative in-vivo images obtained from the breath-hold 2D LGE (a) and 3D LGE (b, c) reformatted at similar short-axis and long-axis views to the 2D images. After motion correction, the motion artifacts in the left ventricle (LV) and myocardium are significantly suppressed, yielding image quality comparable to the breath-hold LGE images.

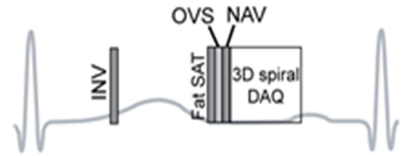

Figure 1: Timing diagram of the proposed 3D free-breathing LGE sequence.

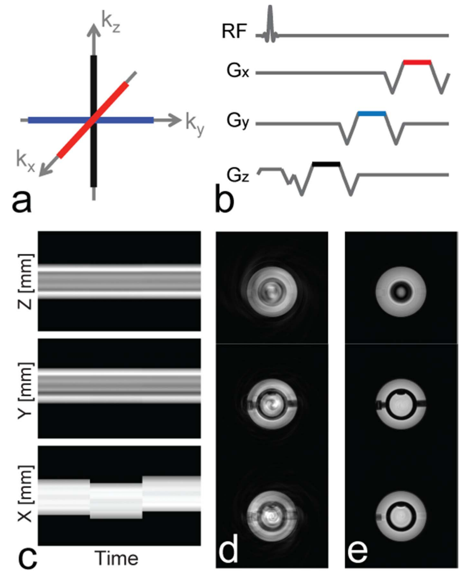

Figure 2: k-space trajectory (a) and readout gradient waveforms (b) for 1D projection acquisitions along 3 dimensions. Phantom testing shows projection images (c), 3D spiral images before (d) and after motion correction (e)

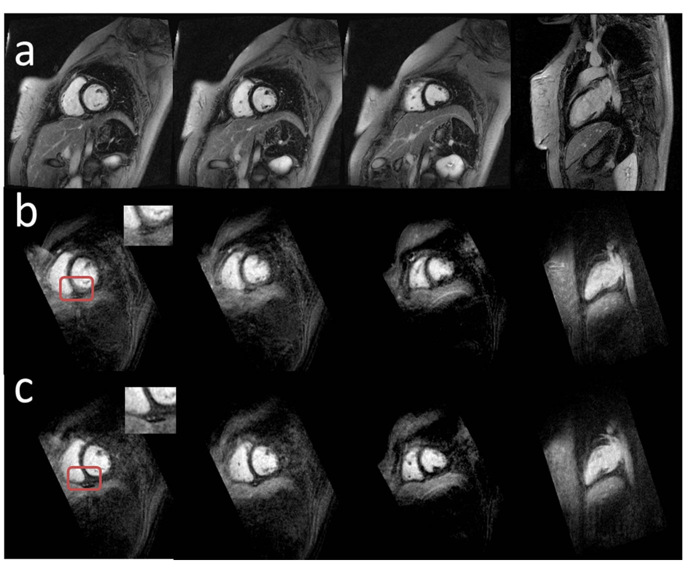

Figure 3: Comparison of conventional 2D multi-slice breath-hold LGE with 3D free-breathing LGE without motion correction (b) and after motion correction(c). The insets highlight the effect of motion correction.

DISCUSSION AND CONCLUSION: We have proposed a new respiratory motion estimator for free-breathing 3D LGE MRI, which allows rapid and accurate 3D motion estimation by combining OVS preparation and 1D projection acquisitions. 3D near-isotropic resolution allows for minimal level of localization complexity during the scan, and provides great flexibility of post-analysis through arbitrary display views. Free-breathing scans will also be beneficial, particularly for heart failure patients many of whom cannot do breath-holds. Additionally, there is significant scan time saving over the standard multi-breath-holds approaches. Strategies to improve the accuracy of motion estimation and validation in a larger clinical cohort are under investigation.

REFERENCES: [1] Kim RJ, et al Circ 1999;100(19):1992-2002. [2] Klein C, et al Circ 2002; 105(2):162-167. [3] Kellman et al JMRI 2012; 36: 529-542. [4] Smith TB et al, MRM 2012; 67:1316-1323.