Improved MRI Assessment of the Left Atrial Appendage using Delayed Enhancement Imaging as Compared to Black Blood Fast Spin Echo Imaging

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INTRODUCTION

Left atrial appendage (LAA) imaging is important as this is a primary site for cardiac thrombus which causes embolic events (1). MRI is well-suited for LAA imaging as it is non-invasive and provides high resolution tomographic images that has the potential to discriminate flowing blood from thrombus. Pulse sequences used for LAA imaging include cine steady state free pressession (SSFP) and black blood fast spin echo (BB-FSE) (2). Delayed enhancement MRI (DE-MRI) has recently been shown to accurately evaluate left ventricular thrombus (3), but its utility for LAA imaging is not known. In this study, LAA imaging by DE-MRI and BB-FSE were compared to a reference of SSFP.

METHODS

Twenty cardiac patients (52 ± 16 years, 76% male, 35% coronary artery disease, 17% atrial fibrillation) underwent clinical MRI at 1.5T (GE Signa HDx 14.0). The imaging protocol included four pulse sequences: 1) cine **SSFP**: TR/TE/FA/BW = 3.7 ms/1.1 ms/60°/±125 kHz, 16 views per segment; 2) **BB-FSE**: TR/TE/BW = 2R-R/40 ms/±62.5 kHz, 32 echoes per segment; 3) **SS DE-MRI** (single shot): TR/TE/TI/FA/BW = 3.6 ms/1.1 ms/300 ms/60°/±125 kHz, SSFP readout, parallel acceleration factor = 2, shot duration = 230 ms; 4) **Seg DE-MRI** (segmented): TR/TE/TI/FA/BW = 7.9 ms/2.0 ms/600 ms/20°/±15.65 kHz, 24 views per segment. SSFP and BB-FSE were performed pre-contrast and DE-MRI 2-3 minutes post-contrast (Gd-DTPA 0.2 mmol/kg). The sequences were matched for imaging planes and spatial resolution (slice thickness = 5 mm, FOV = 28 cm, phase FOV = 0.8, matrix size = 256x160). BB-FSE and DE-MRI images were aquired 600 ms after the ECG trigger. SS DE-MRI required a single breath-hold, while multiple (typically 5-6) breath-holds were necessary for other sequences.

Image analysis for each sequence was performed by experienced physicians blinded to all other quantitative results. LAA dimensions were traced in a pre-defined long axis plane; LAA cross sectional area, orifice diameter (at the junction of the left upper pulmonary vein), and length (orifice-apex) were measured. LAA images were visually scored for quality on a 5-point scale (0=non-diagnostic 1=poor 2=fair 3=good 4= excellent). LAA intraluminal signal artifacts were graded using ROI analysis based on signal intensity ratio between the LAA and the aortic root (SI_{LAA}/SI_{AORTA}), which would be expected to be near equal in the absence of thrombus or artifacts.

RESULTS

The LAA was successfully imaged by SS DE-MRI in 19/20 patients (1 patient had severe parallel imaging artifact) and by Seg DE-MRI in 18/20 (1 had excessive blurring, 1 unable to tolerate breath-hold). Imaging time was 6 ± 1 sec by SS DE-MRI and 69 ± 14 sec (excluding time between breath-holds) by Seg DE-MRI ($p<0.0001$). No patients had LAA thrombus by DE-MRI or SSFP; BB-FSE was non-diagnostic for thrombus in 7/20 patients. Table 1 compares imaging results between pulse sequences. While SS DE-MRI and Seg DE-MRI closely agreed with SSFP, there were significant differences between BB-FSE and SSFP with respect to LAA area ($p<0.0001$) and length ($p=0.02$). Qualitative scores and LAA/aorta signal intensity ratio did not differ between DE-MRI and SSFP. Although BB-FSE provided excellent blood suppression in the cardiac chambers and aorta, it failed to suppress blood signal in the LAA (Fig.1), resulting in lower reader assigned image quality and LAA intraluminal signal 3-fold higher than the aorta (both $p<0.0001$ vs. SSFP).

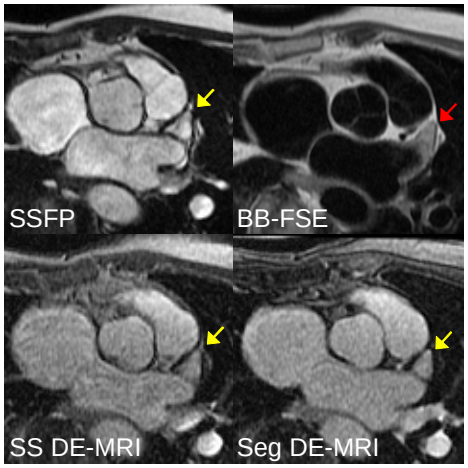

Fig.1. Representative LAA images. Note that while the LAA is well imaged on SSFP and DE-MRI (yellow arrows), BB-FSE yields prominent signal artifact (red arrow), which impairs visualization of the LAA lumen.

CONCLUSIONS

Single shot and segmented DE-MRI provide similar measurements of LAA size and image contrast compared to SSFP. Black blood FSE imaging suffers from severe intraluminal signal artifacts, leading to inaccurate measurements. Due to its ability to provide sub-second data acquisition, single shot DE-MRI is a promising approach to interrogate the LAA and warrants further investigation.

REFERENCES 1. Zabalgoita et al. J Am Coll Cardiol 1998;31:1622-6. 2. Ohyama et al. Stroke 2003;34:2346-9. 3. Weinsaft et al. J Am Coll Cardiol 2008;186:198-205.

Table 1. Comparison of four pulse sequences for LAA imaging (p values refer to comparison with SSFP; bold font indicates $p < 0.05$)

	SSFP	Seg DE-MRI	p	SS DE-MRI	p	BB-FSE	p
Geometric Parameters							
Area (cm^2)	6.6 ± 2.1	6.5 ± 2.2	0.50	6.5 ± 2.4	0.55	5.4 ± 2.0	**<0.0001**
Length (cm)	3.5 ± 0.6	3.4 ± 0.7	0.70	3.3 ± 0.6	0.33	3.1 ± 0.7	**0.01**
Diameter (cm)	2.2 ± 0.6	2.1 ± 0.6	0.57	2.1 ± 0.6	0.27	2.0 ± 0.6	0.09
Qualitative Score	3.6 ± 0.7	3.3 ± 1.3	0.25	3.5 ± 0.9	0.69	1.1 ± 0.9	**<0.0001**
SI_{LAA}/SI_{AORTA}	0.8 ± 0.1	0.8 ± 0.1	0.13	0.8 ± 0.2	0.19	3.0 ± 1.4	**<0.0001**
Imaging Time (sec)	46 ± 9	69 ± 14	**<0.0001**	6 ± 1	**<0.0001**	58 ± 11	**<0.0001**