

High resolution MRI with a spiral k -space trajectory: Atrial wall imaging and late gadolinium enhancement for the assessment of RF ablation lesion transmural in the left atrium.

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Introduction: Late gadolinium enhancement (LGE) in the left atrium (LA) following radiofrequency (RF) ablation of the pulmonary veins (PVs) has been previously demonstrated [1]. However, current LGE techniques do not reach sufficient resolution to determine if ablation lesions are transmural, a factor that can determine the success of an ablation procedure. It has been shown that myocardial thickness in the left atrium can reach as low as 1-2mm [2], therefore a LGE imaging sequence should be sub-millimetre in resolution.

We have combined high resolution imaging of LGE and the LA wall to form a strategy to assess ablation lesion transmural. Both MR scans use a spiral k -space trajectory. This trajectory is a highly efficient sampling scheme, and also allows for a very short acquisition window (minimising cardiac blurring), as each spiral interleaf is typically 10-15ms in duration. Image blurring due to B_0 off-resonance effects is common using a spiral trajectory, however image degradation can be minimized incorporating an off-resonance correction into the reconstruction. We present here initial results from this study.

Methods: Three patients with RF ablation lesions (2 chronic, 1 acute) underwent an MR examination on a 1.5T MR-scanner (Philips Achieva) using a 5-channel cardiac coil. For LA wall imaging, a double inversion-recovery black-blood preparation was used in combination with a multi-slice spiral acquisition (4 slices, 5mm thickness, resolution = 0.8mm^2 , FOV = 200mm^2 , 1 spiral per 2RR intervals, 20ms acquisition per spiral, 15 spirals per slice, FA = 90°). For late-enhancement a two 3D IR-TFE scans were performed 25 minutes after administration of 0.4ml/kg of a Gd-DTPA contrast agent. First, a 3D IR-TFE using a Cartesian k -space trajectory was performed (40 slices, resolution = $1.3 \times 1.3 \times 4\text{mm}^3$, interpolated to $0.7 \times 0.7 \times 2\text{mm}^3$, acquisition window of 150ms, FOV = $341 \times 300\text{mm}^2$, FA = 20°). Following this scan, a 3D IR-TFE stack-of-spirals scan was performed (10 slices, resolution = $0.8 \times 0.8 \times 4\text{mm}^3$, interpolated to $0.4 \times 0.4 \times 2\text{mm}^3$, FOV = 200mm^2 , 1 spiral per 2RR intervals, 20ms per interleaf, 18 interleaves per slice, FA = 90°). For all scans, ECG triggering was set to atrial systole, as determined from a 2D cine scan. Respiratory navigation was used to minimise breathing motion artefacts, using a 5mm gating window. Corresponding B_0 maps were acquired to correct strong field inhomogeneities. Images were reconstructed offline in MATLAB and a conjugate-phase reconstruction, based on a Chebyshev approximation of the off-resonance term [3], was used to correct for B_0 field inhomogeneities.

Late enhancing areas were automatically segmented by thresholding at a level defined by the mean of an ROI in the LA blood-pool plus 3 SDs of the ROI. The thresholded LGE images were fused with the atrial wall MR images to allow for visualisation of the enhancing areas in relation to the location of the atrial wall. Profiles were created across the atrial wall and the thresholded LGE in the regions that exhibited enhancement (points 1 and 2 in Figure 1, and the posterior segment of the left inferior (LI) PV, point 3) to assess the thickness of the enhancement in relation to the wall thickness.

Results: Figure 1 shows an example of the atrial wall images, the high resolution LGE images and the fusion of the segmented LGE and atrial wall respectively. Enhancement was observed on the anterior wall adjacent to the Right superior (RS) PV, as shown in the figure, as well as in the regions of the RI and left superior (LS) PVs, on both the posterior and anterior walls. Compared to the lower resolution, Cartesian LGE enhancement images, the areas of enhancement are more clearly defined and images appear sharper due to the increase in resolution. The profile thickness that were measured are summarised in Table 1.

Discussions and conclusions: This work sets out a framework to measure RF ablation lesion transmural. The novel fusion of atrial wall images and high resolution LGE images allows for the assessment of the thickness of the enhancement compared to the thickness of the left atrial wall. The use of a spiral k -space trajectory allows for the MR images to be acquired at higher resolution within an acceptable scan duration whilst maintaining a very short acquisition window, thus minimising cardiac motion artefacts. From the wall thicknesses measured at the three different locations, two locations had enhancement and wall thicknesses values in agreement. In one location, the wall thickness was greater than the enhancement thickness indicating potential incomplete transmural. Future work will focus on increasing coverage of the LA and to shorten the time duration between atrial wall and late enhancement scans to avoid misregistration due to motion.

References: [1] Peters *et al.* Radiology 2007;243:690-5 [2] Ho *et al.* J. Cardiovasc. Electrophysiol. 1999;10:1525-33 [3] Chen *et al.* MRM. 2008;60:1104-111

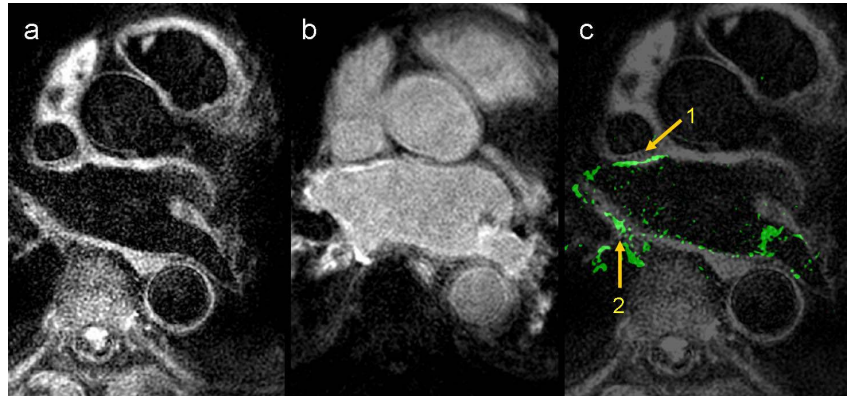


Figure 1: Transverse view of the left atrium as seen from the (a) Atrial wall (b) spiral- LGE and (c) the fusion of the atrial wall with the thresholded LGE images

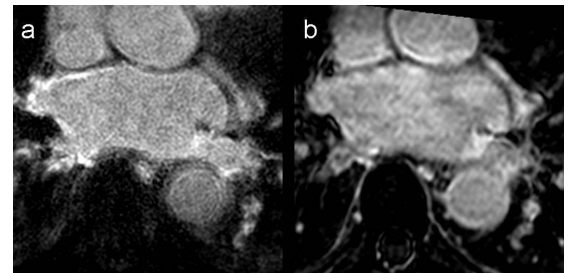


Figure 2: Transverse view of the left atrium as seen from the (a) High resolution spiral- LGE and (b) The lower resolution Cartesian LGE.

Point	Wall Thickness (mm)	Enhancement Thickness (mm)	Difference (mm)
1	3.0	3.0	0
2	4.6	3.1	1.5
3	3.4	3.1	0.3

Table 1: Measured atrial wall thicknesses and late enhancement thicknesses at three enhancing locations within the LA.