

Late gadolinium enhancement imaging with dynamic_TI in the atrial fibrillation population

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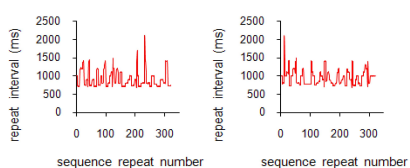
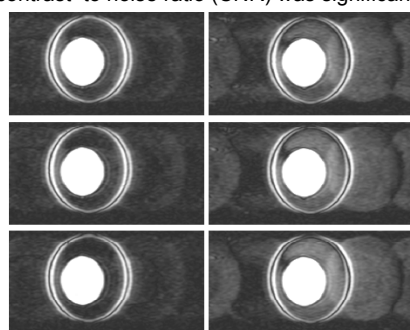
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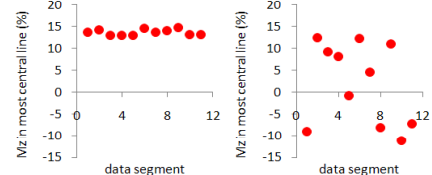
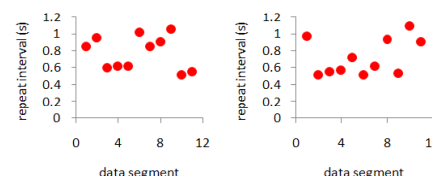
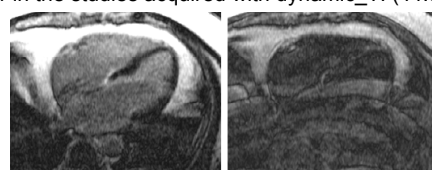
Introduction: There has been considerable interest in high resolution 3D late gadolinium enhancement (LGE) imaging in the atrial fibrillation (AF) population, both pre and post RF ablation (1,2). Unlike conventional studies, these are performed with single R-wave gating to reduce the acquisition duration and the effects of gadolinium wash-out. However, single R-wave gating increases the sequence susceptibility to RR interval variations which result in variable magnetization recovery between sequence repeats and ghosting and poor nulling of normal tissue. This is exacerbated by missed cardiac triggers and the number of poor quality studies in the AF population is high. An adaptive inversion recovery preparation has previously been demonstrated in a 2D phantom acquisition (3). In this study, we implement such a technique for improved imaging in the AF population.

Methods: An inversion-prepared segmented FLASH sequence was modified so that the inversion time (TI) varied automatically from beat-to-beat (dynamic_TI) based on the time since the last sequence repeat using the formulation of Fleckenstein (4). The gating delay (GD) was also modified so that the timing of the acquisition window within each cardiac cycle remained fixed ie $TI + GD = \text{constant}$. The dynamic_TI algorithm was demonstrated in a phantom mimicking a short axis slice of the myocardium and in 5 patients with AF. In each patient, repeated 2D breath-hold acquisitions were performed with single R-wave gating, both with and without the dynamic_TI algorithm. Over the 5 patients, a total of 21 acquisitions were performed with the dynamic_TI algorithm and 21 without. Both 2D and 3D phantom data were acquired, while in vivo, time constraints only allowed the acquisition of 2D studies. Sequence repeat times were stored for subsequent simulation of the evolution of the longitudinal magnetisation (M_z) throughout the acquisitions.

Results: Figure 1 shows a 3D phantom acquisition both with (left) and without (right) the dynamic_TI algorithm, together with plots of the sequence repeat time intervals throughout each 5minute acquisition period. The variability in the repeat time intervals was similar for both acquisitions (912 \pm 226ms vs 959 \pm 204ms), with the dynamic_TI algorithm resulting in much less ghosting and better 'myocardial' signal suppression. Figure 2 shows 2D acquisitions with and without dynamic_TI in a patient with fast AF, together with the sequence repeat time intervals throughout each acquisition and the simulated M_z of blood for the most central phase encode lines in each data segment. The dynamic_TI algorithm has resulted in minimal ghosting and good myocardial suppression despite the highly variable sequence repeat time intervals, with the simulated M_z variation throughout the acquisition being low. In this acquisition, the TIs implemented ranged from 185-263ms. In our patients, the sequence repeat times varied both between patients and between repeat acquisitions in the same patient. Consequently, the need for the dynamic_TI algorithm also varies between patients and between repeat acquisitions within a single patient. In Figure 3 for example, while both images were acquired without dynamic_TI, the sequence repeat time variabilities in the acquisitions differed (710 \pm 218ms and 902 \pm 365ms), leading to very different image quality. On average, however, the blood-myocardium contrast to noise ratio (CNR) was significantly higher in the studies acquired with dynamic_TI (44.5 vs 24.3, $p = 0.036$).



(a) with dynamic_TI (b) without dynamic_TI



(a) with dynamic_TI (b) without dynamic_TI

Figure 1: Three contiguous slices from a 3D acquisition both with (a) and without (b) the dynamic_TI algorithm (brightness and contrast adjusted to show ghosting in both in plane and through plane directions). The sequence repeat time intervals throughout the acquisitions are shown below. The nulling is better with dynamic_TI and the images have much less ghosting.

Figure 2: 2D LGE in a fast AF patient with (a) and without (b) dynamic_TI. Sequence repeat time intervals are shown (middle) together with simulations of M_z of blood for the most central line in each segment (bottom). The average RR interval was ~500ms but missed triggers resulted in average sequence repeat times of ~700ms for both. Dynamic_TI has resulted in less M_z variation and better image quality.

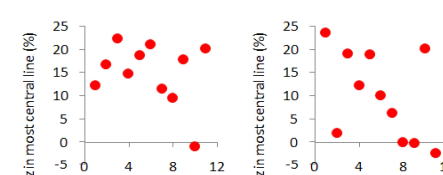
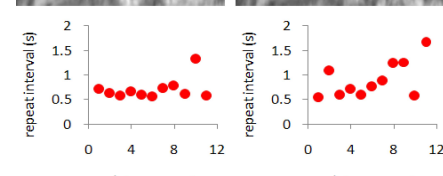
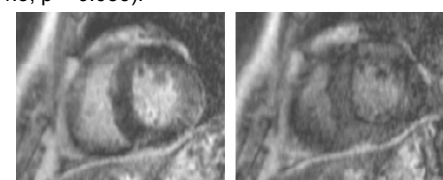


Figure 3: Repeat 2D LGE images acquired without dynamic_TI in the same patient. Sequence repeat time intervals throughout the acquisitions are shown (middle) together with simulations of M_z of blood for the most central lines in each data segment (bottom). The heart rate variability and M_z variability in the left hand acquisition is less than that in the right, resulting in better image quality.

Conclusion: Image quality of LGE depends on heart rate variability and varies between patients and between repeat acquisitions in the same patient. We have shown that dynamic adaptation of the inversion time for each cardiac cycle is feasible and can result in less ghosting, improved nulling of normal myocardium and increased blood-myocardium CNR. Application to 3D studies should result in improved acceptability rates.

References: (1) Peters et al, Radiology 2007 (2) McGann et al, JACC 2008 (3) Krishnamurthy et al, SCMR 2010 (4) Fleckenstein et al, Radiology 1991