Motion correction in post-injection dynamic cardiac T_1-mapping: preliminary results

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Target audience – MR scientists and clinicians interested in motion correction, T_1 mapping and cardiac MRI.

Purpose – Quantification of myocardium fibrosis may be useful to characterize Duchenne Muscular Dystrophy (DMD) heart disease. For that purpose, Extra-Cellular Volume (ECV) can be computed from pre- and post-contrast myocardial T_1 quantifications. However, this technique requires the acquisition of numerous images with different contrasts. Thus, the robustness of the quantification can be impaired by misregistration and motion artifacts, especially since patients with DMD can barely hold their breath. Here, we propose a motion compensation method that can be applied on multi-contrast (MC) acquisitions. The main idea is to take advantage of the information shared between the images.

Methods – ***Subject:*** two patients with DMD, males, 16 & 19 y.o. ***Dataset:*** At 1.5T (GE, Signa HDxt), 8 saturation-recovery SMART$_1$Map acquisitions[1] were acquired in short-axis and ECG-triggered in diastole. These acquisitions were clustered in 5 groups (according to the post-injection time: {0',0'},{2'},{3'},{11',12'},{22',23'}) of 4 images each (Saturation Time TS~[50,750,2100,3500ms]). One LGE image was acquired on the same slice at 15'. ***The Reconstruction method*** is adapted from the GRICS method[2] that is a joint reconstruction of a non-rigid motion model α and the corresponding motion-corrected image ρ. The conventional GRICS could be applied to each set of 1 or 2 k-spaces s_i independently. However this would not make an optimal use of the redundant information resulting in a suboptimal reconstruction. Therefore, two adaptations have been made (MC-GRICS – see following table): a) shared optimization of the motion model α over the whole exam, b) joint reconstruction of multi-contrast images under a gradient sparsity constraint[3]. If *E* stands for the encoding operator, *R* the translation of the optical flow equation through *E*, and *G* the local probability of occurrence of a gradient over the whole data-set, the problem consists in the joint optimization of the following system:

conventional GRICS	+ shared optimization of the motion	+ with gradient sparsity constraint (MC-GRICS)
$\forall \text{contrast } i \begin{cases} s_i = E(\alpha_i)\rho_i \\ s_i - E(\alpha_i)\rho_i = R\delta\alpha_i \end{cases}$	$\begin{cases} \forall \text{contrast } i \;\; s_i = E(\alpha)\rho_i \\ \mathbb{s} - \mathbb{E}(\alpha)\mathbb{p} = \mathbb{R}\delta\alpha \end{cases}$	$\begin{cases} \mathbb{p} = \min_{\mathbb{p}} \left\| \frac{\nabla \mathbb{p}}{G} \right\| \quad s.t. \quad \mathbb{s} = \mathbb{E}(\alpha)\mathbb{p} \\ \mathbb{s} - \mathbb{E}(\alpha)\mathbb{p} = \mathbb{R}\delta\alpha \end{cases}$

Data analysis: Two ROIs corresponding to areas with and without enhancement were drawn by an experimented cardiologist from the LGE image when an enhanced area appeared (patient#1). The pre- and post-injection T_1 evolution was assessed in terms of mean ± confidence interval (ROI-wise fitting).

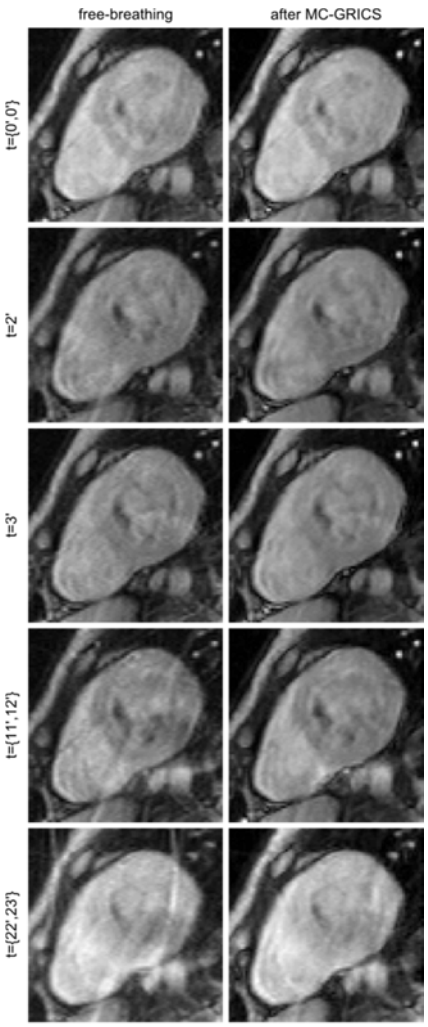

Fig.1 Pre and post injection images obtained before & after motion correction with MC-GRICS (patient #2)

Results – In both patients, motion artifacts have been reduced with MC-GRICS (fig. 1). We can observe a significant difference in the T_1 evolution between the 2 ROIs (fig. 2) from the T_1 computed after MC-GRICS correction. The significance of this difference was lower without the motion correction (p-value<0.01 without correction instead of p=<10^{-5} with MC-GRICS). In the enhanced ROI, T_1 is higher before injection and lower after injection, and the uptake is slower.

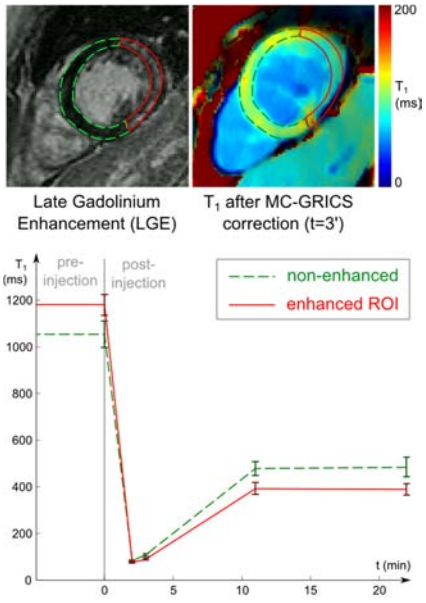

Fig.2 - Dynamic follow-up of myocardial T_1 on two ROIs (patient #1, with MC-GRICS)

Discussion – The different of dynamics between the 2 ROIs is concordant with a higher ECV and a higher importance of diffusion over perfusion in the uptake process in the enhanced ROI. The proposed motion correction method was shown to improve the differentiation between regions with different stages of fibrosis from dynamic T_1-quantification, in free-breathing, on one patient who can barely hold his breath.

Conclusion – This study shows the feasibility of correcting intra and inter-acquisition motion for the purpose of improving the dynamic characterization of myocardial T_1 in free-breathing on DMD patients. In a future work, we would like to extract pseudo-quantitative parameters and compute the ECV for a better discrimination and characterization of the different stages of fibrosis.

References – 1. Slavin et al.,SCMR,2013 ; 2. Odille et al.,MRM,2008 ; 3. Menini et al.,ESMRMB,2013