Motion Correction for 3D T_1 Mapping using GRICS: Phantom Validation

Anne Menini[1], [2], Hélène Clique[1], [2], Marine Beaumont[3], [4], Jacques Felblinger[1], [2], Freddy Odille, [12]
[1]IADI, Nancy-Université, Nancy, France; [2]U947, INSERM, Nancy, France; [3]CIT801, INSERM, Nancy, France; [4]CHU de Nancy, Nancy, France

INTRODUCTION

T_1 mapping is a valuable tool to analyze myocardial fibrosis or liver perfusion. For better characterization, 3D imaging is highly desirable. Unfortunately, these 3D acquisitions exceed tolerable breath hold time. Moreover, most T_1 mapping methods, such as the variable flip angles method, require several acquisitions with varying imaging parameters. But motion artifacts and misregistrations affect the quantification. In this work, we propose a T_1 mapping reconstruction method that includes motion correction. This method is a variant of T_2 GRICS proposed by Lohezic et al. [1], adapted to T_1 and 3D.

THEORY

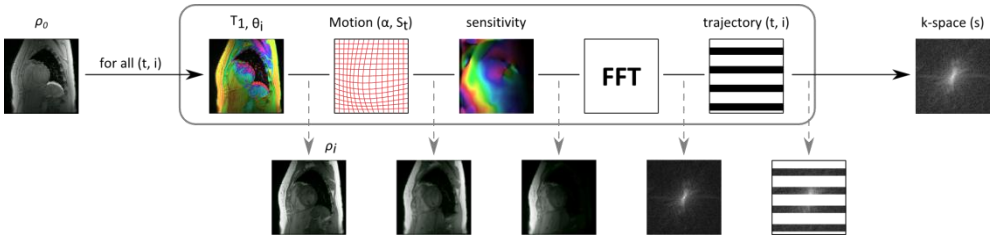
T_1 weighting: The approximation of short flip angles (eq. 1) is used to describe the image weighting, where ρ_i stands for the T_1 weighted image, ρ_0 the image without T_1 weighting, and θ_i the current flip angle.

$$\rho_i = \rho_0 \frac{\sin\theta_i \left(1 - e^{-\frac{TR}{T_1}}\right)}{1 - e^{-\frac{TR}{T_1}} \cos\theta_i} \quad (1)$$

Motion Model*:* Each physiological motion is described by a non-rigid motion model α_k. Thus, global motion U can be described by a linear combination of the motion models weighted by the associated physiological sensors S_k (ECG, respiratory belt, etc.) (eq. 2).

$$U(x,t) = \sum_k \alpha_k(x) S_k(t) \quad (2)$$

GRICS algorithm: GRICS is an adaptive reconstruction method proposed by Odille et al. [2] that takes the physiological sensors into account in order to correct for motion that occurs during the acquisition. It is based on the inversion of coupled linear systems that describes the imaging system (fig. 1). If the motion model is known, weighted images ρ_i can be obtained (eq. 3). Then, the fitting of equation 1 gives us the T_1 map. If T_1 weighting is also simulated in the imaging system, we obtain the morphological image ρ_0 shared by all the acquisitions (eq. 4). Since the motion model is shared between all acquisitions, misregistration problems are also avoided. The motion model is updated by solving for a linearized expression of the residual error with respect to the error in motion model parameters $\delta\alpha_k$ (eq. 5). A fixed point multiresolution scheme is used to invert the system of equations formed by equations 3, 4 and 5.



$$\forall i, \quad s_i = E(\alpha)\rho_i \quad (3)$$

$$s = E(\alpha, T_1)\rho_0 \quad (4)$$

$$s - E(\alpha, T_1)\rho_0 = R(\alpha, T_1)\delta\alpha \quad (5)$$

Figure 1 - The imaging system is made up of a weighting, a distortion, a sensitivity model, a Fourier transformation and a trajectory mask.

MATERIALS AND METHODS

Acquisition: At 3T (SIGNA HDxt, GE Healthcare, Milwaukee, WI), two data sets were acquired on a homemade phantom made up of eight tubes of gadolinium dissolution (0 to 0.875 mmol.L^{-1}) bathing in water. 3D FSPGR sequences (TE=3.3ms, TR=6.7ms, FOV=16x16x10cm) with variable flip angles (2, 5 and 11°, each repeated three times) were used. With a static phantom, the first data set was acquired and excitation field (B1) was reconstructed from two EPI acquisitions (same parameters with FA1/FA2=60/120° and 120/240°). Next, the phantom was animated thanks to a breathing apparatus translating a platform in plane and through plane. Then, the second data set was acquired while signal from a respiratory belt was collected by a custom Maglife patient monitoring system (Schiller Medical, France) and recorded with a dedicated home-made hardware presented in [3].

Data analysis: Three T_1 maps were generated. Two maps were obtained with linear fitting on the two sets of data (with and without motion) and the third one with the new 3D T_1 GRICS reconstruction with the moving phantom. A B_1 correction was applied to each map following the method proposed by Cheng et al. [4]. Results were presented as the mean ± standard deviation of T_1 values in ROIs encompassing the tubes.

RESULTS

T_1 values obtained with GRICS correction show significant differences ($p<0.001$) compared to those with uncorrected motion (fig. 2) and are in good agreement with those without motion. Uncorrected T_1 values are always overestimated.

DISCUTION & CONCLUSION

High T_1 values obtained with uncorrected motion show that T_1 values can be corrupted by surrounding T_1 values due to motion artifacts. In addition, since T_1 values obtained without motion can be considered as the reference, GRICS significantly improves the accuracy of T_1 for acquisitions taken while motion occurs. This method can be applied to correct breathing artifacts in myocardial T_1 mapping, or liver and breast perfusion.

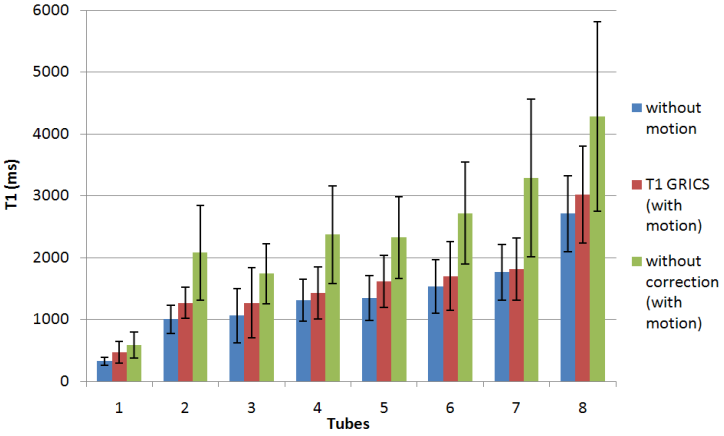


Figure 2 - Comparison of T1 maps obtained without motion and with motion, with and without GRICS correction

REFERENCES

[1] Lohezic et al., Proc. ISMRM 2010, 2958 ; [2] Odille et al., MRM 60:146–157 (2008); [3] Odille et al., IEEE TBME 54: 630-640 (2007); [4] Cheng et al., MRM 55:566–574 (2006)