Free breathing myocardial T2 measurements

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INTRODUCTION: Quantitative measurements of Magnetic Resonance tissue parameters is a valuable tool for tissue characterisation and functional imaging. For instance, myocardial T_2 quantification is used to detect early rejection of heart transplant [1]. These T_2 values are usually estimated by performing several black blood FSE sequences with different Echo Times (TE), thus requiring multiple breath holds. These successive apneas could lead to misregistration between images and to patient discomfort. A method combining T_2 estimation, respiratory motion estimation [2] and motion compensated reconstruction [3] is presented, allowing free breathing myocardial T_2 measurements. It was evaluated on five healthy subjects.

MATERIAL & METHODS:

MRI experiments: Five healthy volunteers underwent cardiac examination at 3T (SIGNA HDxt, GE Healthcare, Milwaukee, WI). Two sets of 10 images with different TE were performed with a conventional black blood FSE sequence at mid cavity short axis view, one during breath hold (BH-FSE) and the other while free breathing (FB-FSE). The same parameters (TI=500ms, TR=2RR, ETL=16, FOV=36cm, BW=62.5kHz, slice thickness=10mm) were used, except for the matrix size set at 128x256 in order to keep the acquisition time compatible with breath holding, whereas it was set to 256x256 for free breathing data. In both series of images, the TE values were ranging from 10ms to 75ms. Signals from a respiratory belt and an ECG sensor were carried by a custom Maglife patient monitoring system (Schiller Medical, France) and recorded with a dedicated home-made hardware presented in [2].

T_2 measurements: For the standard breath hold acquisitions, the 10 images were first registered. A T_2 map was then obtained on a pixel-by-pixel basis by measuring the pixel intensities in the series of increasing TE images $\rho(TE)$ to give an exponential decay curve. An exponential trend-line was fitted with the following equation:

$\rho(TE) = \exp\left(-TE/T_2\right)\rho_0$ (Eq. 1), where ρ_0 is a proton density weighted image.

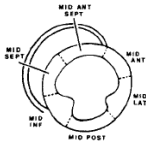

Fig.1 : Diagram of the 6 left ventricle ROI. Extracted from [4].

The left ventricle myocardium had also been divided into 6 segments according to the AHA recommendations [4] (*Fig. 1*). The mean value of each ROI was then used to get 6 myocardial T_2 values (Eq. 1).

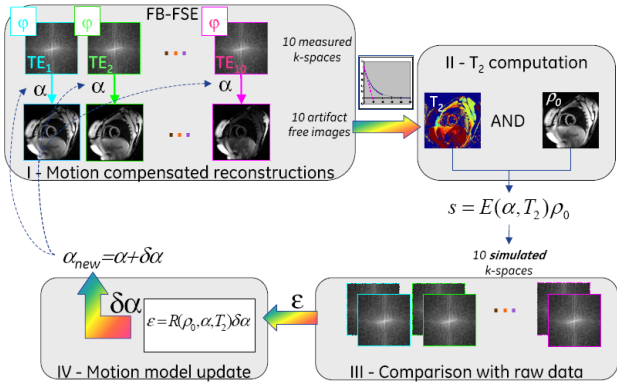

Fig.2 : Free breathing T2 measurements.

Free breathing reconstruction: To deal with free breathing acquisitions, a respiratory motion model has been introduced [3]. Displacement fields $u(r,t)$ are estimated at each echo t using physiological signals $S_k(t)$:

$u(r,t) = \sum_{k=1}^{K} S_k(t)\alpha_k(r)$ (Eq. 2), where α_k are learned motion coefficients.

To reconstruct both image ρ_0 and T_2 map from free breathing data s, GRICS algorithm [3] has been extended to include T_2 computation in the reconstruction scheme resulting in four steps repeated iteratively using a multi resolution fixed point scheme (*Fig. 2*).

(I) A motion compensated reconstruction is first performed consisting in finding the pseudo-inverse of the generalized encoding operator $E(\alpha)$ which includes spatial transformations estimated using Eq. 2. One artifact free image $\rho(TE)$ is thus reconstructed for each TE. *(II)* A T_2 map is then computed according to Eq. 1. During this fitting process, a proton density image ρ_0 is also obtained. *(III)* Using the generalized operator $E(\alpha,T_2)$ which includes both spatial transformations and T_2 weighting, 10 k-spaces are simulated and compared to those acquired by the scanner. *(IV)* The resulting residuum ε is finally used with the linear operator $R(\rho, \alpha, T_2)$ to update the motion model coefficients. Two respiratory inputs (a respiratory belt and its time derivative) were used to determine the respiratory motion, α_k being initialized to zero.

RESULTS: Free breathing T_2 values of the 6 short axis mid-cavity segments were compared to those obtained using the standard breath hold technique. There was no significant difference between the two sets of measurements (paired Student T-test, p=0.32). The free breathing T_2 maps are in good agreement with the breath hold ones and respiratory artifacts are widely reduced in ρ_0 (*Fig. 3*).

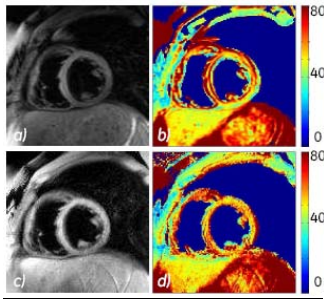

Fig. 3:Results obtained on healthy volunteer in **Breath hold***: a)BH-FSE (TE=40ms) and b) T_2 map; and in* **Free breathing***: c) image ρ_0 and d)T_2 map.*

DISCUSSION & CONCLUSION: Thanks to motion compensated reconstruction and iterative motion estimation, both morphological image ρ_0 and functional T_2 map have been obtained from free breathing acquisitions. This free breathing T_2 calculation method can be applied on other organs, such as liver, and could be extended to T_2* or T_1 measurements.

REFERENCES: [1] Marie et al., JACC 37: 825-831 (2001);
[2] Odille et al., IEEE TBME 54: 630-640 (2007); [3] Odille et al., MRM 60: 146-157 (2008);
[4] Cerqueira et al., Circulation: 539-542 (2002).