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Self-navigated three-dimensional cardiac T_2 mapping at 3T

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Background

Cardiac T_2 mapping using a variable T_2 preparation module (T_2Prep) has recently gained attention for its ability to quantify the extent of edema (Giri, JCMR 2009). Due to time constraints, the T_2 maps are commonly acquired as one or several two-dimensional slices, while the underlying pathology has a three-dimensional (3D) structure. The next logical step would therefore be to exploit recent hardware and software advances to directly acquire 3D T_2 maps. To this end, we tested the feasibility of using a self-navigated 3D radial acquisition with a variable T_2Prep for 3D T_2 mapping at 3T.

Methods

Approval was obtained from the institutional review board. A 3D self-navigated undersampled balanced steady-state free precession (bSSFP) sequence (TR/TE=2.6/1.33ms, matrix 128^3, flip angle 70°) with a spiral phyllotaxis radial 3D trajectory (Piccini, MRM 2011) was implemented on a 3T clinical system (Skyra, Siemens AG). This self-navigated pulse sequence allows free breathing acquisitions with 100% scan efficiency, while ECG triggering every 2 heartbeats and TE_{T2Prep}=60/30/0ms allow for a total acquisition time of ~18min with an isotropic spatial resolution of $(1.7mm)^3$. The datasets were registered using 3D affine registration (Studholme, Med Image Anal 1996). Through Bloch equation simulations, the heart-rate-dependent T_1 -relaxation-related offset in the T_2-fitting equation was ascertained. Subsequently, the validity and accuracy of the T_2 fitting was tested in a phantom whose "true" T_2 values were previously determined. The in vivo robustness of the T_2 determination was then tested in 9 healthy adult subjects. Finally, the sequence was applied for the detection of edema in a 75-year-old male infarct patient after revascularization of his proximal left circumflex.

Results

The Bloch equation simulations of the pulse sequence demonstrated that the input T_2 value could be accurately fitted from the magnetization M with the equation $[M=M_0 e^{-TET2Prep/T2} + 0.08M_0]$, while the fitted T_2 had only a ~3% variation over the common range of heart rates (Fig.1A). The phantom T_2 maps demonstrated high homogeneity and fitting accuracy with the 3D sequence matching the 'true' value to within 1% (Fig.1B). The volunteer study (Fig.2A-C) suggested good agreement with previously reported T_2 values at T_2=39.3±3.9ms (Van Heeswijk, JACC Imaging 2012, in press). A region of significantly elevated T_2 (60.4±9.1 vs. 41.0±4.5ms) was identified in the patient in the infero-lateral myocardium of the left ventricle (Fig.2D,E), consistent with the findings on X-ray coronary angiography.

Conclusions

The proposed technique provides an easy and time-efficient way to obtain accurate isotropic T_2 maps of the whole heart. Accurate T_2 values were obtained in the phantom, while those in volunteers are consistent with previously reported values. The preliminary patient study demonstrated elevated T_2 in the infarcted region as expected.

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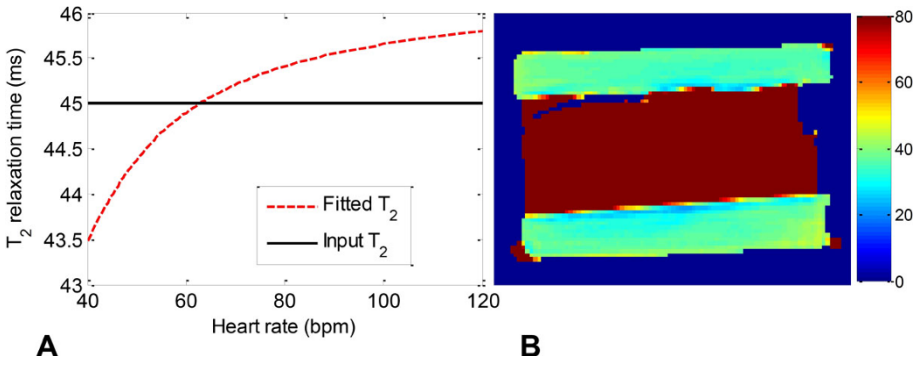

Figure 1 A) Bloch equation simulation demonstrating that the dependence of the T_2 fit of the magnetization on the heart rate due to varying T_1 relaxation is relatively low (between 43 and 46ms, a variation of 3%), while the "true" input T_2 was 45ms. B) T_2 map of a phantom that approximates arterial blood and myocardium. The T_2 values of the two 'myocardium' compartments (turquoise) are very similar at 35.3±2.1ms and 35.5±2.4ms and within 1% of the "'true" T_2 value of 35.6ms.

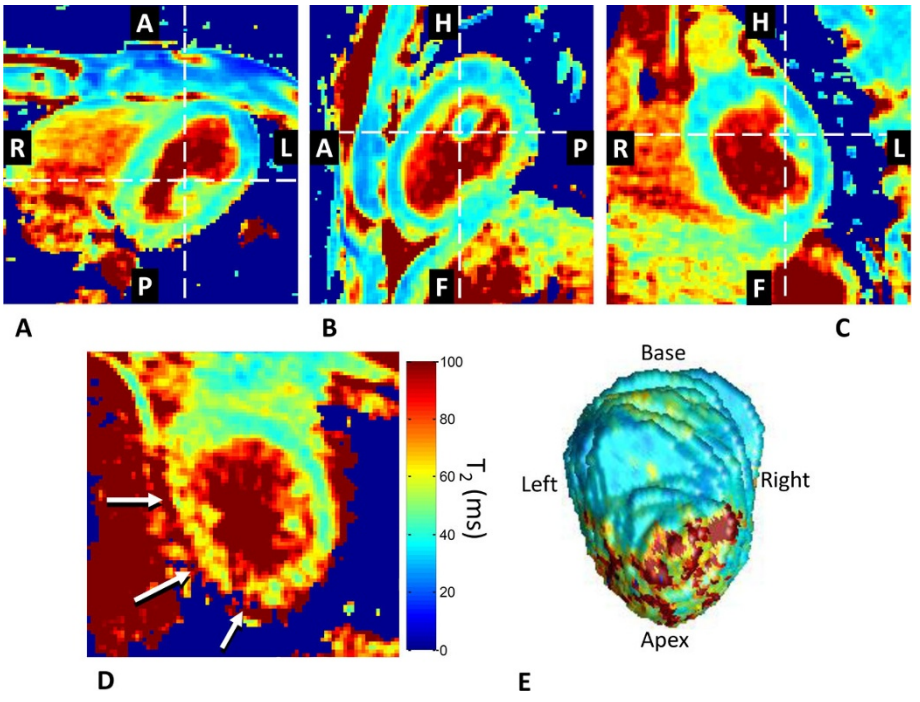

Figure 2 A-C) Axial, sagittal and coronal multi-planar reformatted T_2 maps through the LV of a healthy volunteer. The myocardium is well defined and T_2=41.3±2.1ms. D) A sagittal T_2 map of a patient with a subacute myocardial infarction demonstrates elevated T_2=62.4±9.2ms in the inferior and infero-lateral segments (arrows). E) 3D segmented LV at a sub-endocardial surface as seen from a posterior position, with a clearly visible inferior and infero-lateral infarction.

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