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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 ($T_2$Prep) 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 $T_2$Prep 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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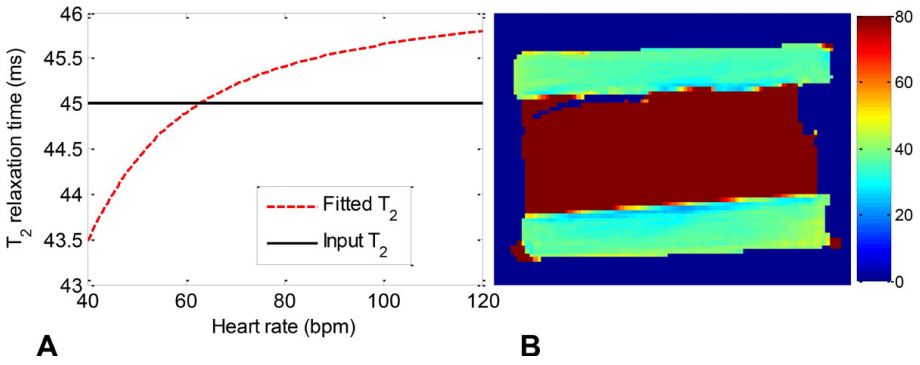


**Figure 1** A) Bloch equation simulation demonstrating that the dependence of the $T_2$ fit of the magnetization on the heart rate due to varying $T_1$ relaxation is relatively low (between 43 and 46ms, a variation of 3%), while the "true" input $T_2$ was 45ms. B) $T_2$ map of a phantom that approximates 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.

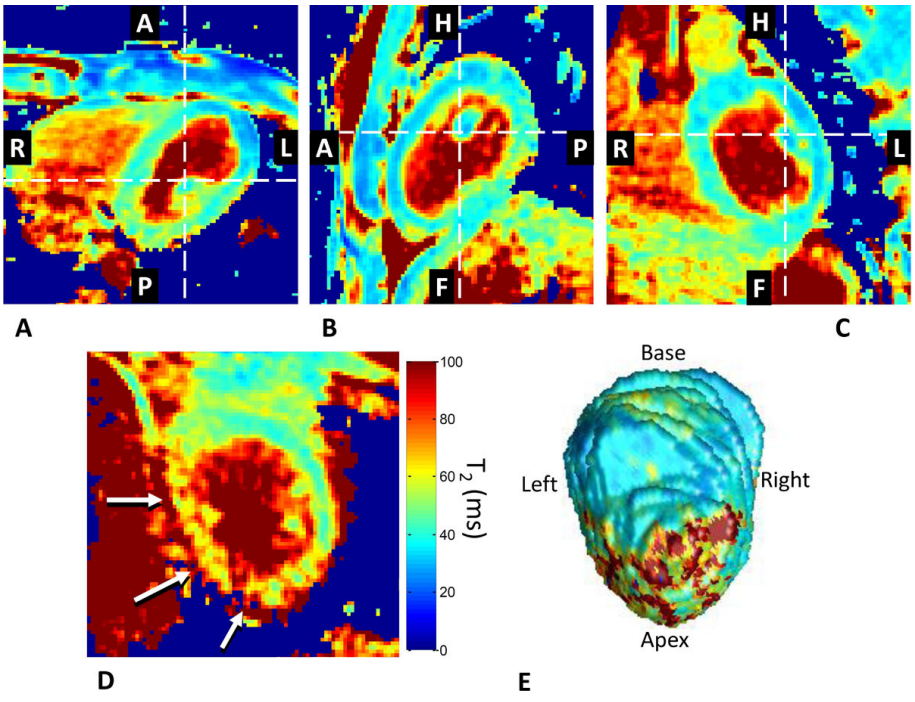


**Figure 2** A-C) Axial, sagittal and coronal multi-planar reformatted $T_2$ maps through the LV of a healthy volunteer. The myocardium is well defined and $T_2$=41.3±2.1ms. D) A sagittal $T_2$ map of a patient with a subacute myocardial infarction demonstrates elevated $T_2$=62.4±9.2ms in the inferior 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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