Black-Blood T1 Mapping for Quantitative Molecular Coronary Vessel Wall Imaging using Elastine-Binding Contrast Agents

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Introduction – MR coronary vessel wall imaging has been shown to provide morphologic information including vessel wall thickness and the extent of atherosclerotic plaque burden (1). Furthermore, molecular MRI using target specific contrast agents (CA) allows imaging of biologic targets and processes, thereby providing complementary information with regard to plaque composition and activity (2). However, an absolute quantification of CA is desirable in order to study the progression of the disease, or for a therapy follow-up. T1 (3) or T2* mapping can be used for this purpose. However, T1 mapping in the coronary vessel wall is particularly challenging due to partial volume effects and cardiac- and respiratory motion, requiring breath-holding and limiting the available spatial resolution. To overcome these drawbacks, an ECG-triggered, navigator-gated, segmented black-blood T1 mapping sequence providing sufficient spatial resolution to quantify CA concentration in the coronary vessel wall was implemented. First results obtained in a swine model of coronary injury using an elastin-targeted CA are reported.

Methods - All experiments were performed on a 1.5T clinical MR scanner (Achieva, Philips Medical Systems) equipped with a 5-element coil array. An ECG-triggered, navigator-gated (5mm gating window) saturation recovery sequence was employed as shown in Fig.1. A spatially selective saturation (S) pulse excluding the right hemi-diaphragm was employed to allow for navigator gating. Imaging was performed with varying saturation delays TS, providing n=10 images with different T1 weighting. A 3-parameter exponential model was fitted to the data to obtain absolute T1 values. To reduce partial volume effects, the arterial blood signal was suppressed using a regional saturation (REST) pulse upstream of the imaging slice (cf. Fig. 2). A 2D SSFP sequence (α=60°, TR/TE=4.2/2.1 ms, 32 readouts per cardiac cycle, resolution 0.89×1.00×8mm) was used for data readout in late diastole. A cross-sectional T1 map of the proximal LAD was measured in a swine model with vessel wall injury resulting from an earlier stenting procedure. The measurements were performed 45 minutes post administration of 0.1mmol/kg of elastin-targeted CA (BMS753951, Bristol Myers Squibb, Billerica, MA, r1=12mmol^{-1}s^{-1}). Total scan time was 4 minutes. A conventional, T1 weighted image acquired with a black-blood double inversion sequence as described in (1) was obtained for a reference.

Results – The conventional T1 weighted black-blood viability image is shown in Fig. 3. The focal accumulation of CA clearly delineates the LAD vessel wall (solid arrow). A quantitative T1 map acquired with the present technique is shown in Fig. 4. Excellent cardiac- and respiratory motion correction as well as good blood suppression were achieved, and the T1 in the LAD vessel wall was quantified with high spatial resolution. A significant shortening of T1 (366±77ms) was observed, which corresponds to a focal CA concentration of 0.13mMol in the LAD vessel wall, whereas a concentration of approx. 0.03 mMol can be expected in the blood volume 45 minutes post administration (4).

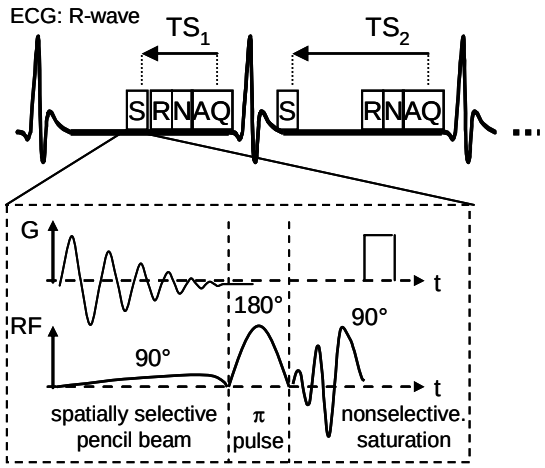

Fig 1. ECG-triggered, navigator (N) gated saturation recovery sequence used for the T1 measurement. A spatially selective saturation pulse (S) sparing the right hemi-diaphragm is performed with different delays TS from the navigator (N) gated image acquisition.

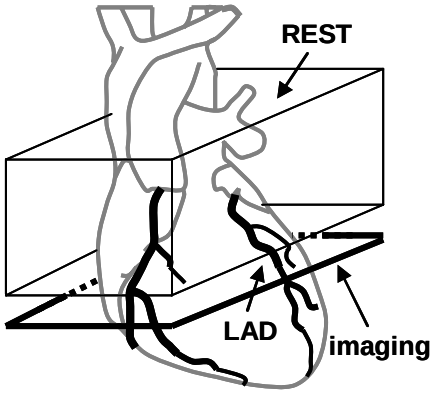

Fig 2. Planning procedure. A 2D slice is prescribed perpendicular to the left anterior descending coronary artery (LAD). A regional saturation (REST) pulse saturates the blood signal upstream of the imaging slice.

Conclusion – We could demonstrate that this novel ECG-triggered, navigator-gated T1 mapping sequence suppresses cardiac and respiratory motion effectively and provides T1 maps of the coronary vessel wall with sub-millimeter spatial resolution, while blood suppression reduces partial volume effects. A significant higher CA concentration in the vessel wall compared to the blood pool verifies the binding mechanism of the employed CA. This technique may be useful for monitoring response to therapy or to study the progression or regression of atherosclerosis in animal models and in patients.

(1) Fayad et al. Circulation 2000; 102:506
(2) Flacke et al. Circulation 2001; 104:1280
(3) Karlsson et al. JMRI 2000; 18:947
(4) Mamourian et al Phys Ch Phys Med NMR 1984;16:123

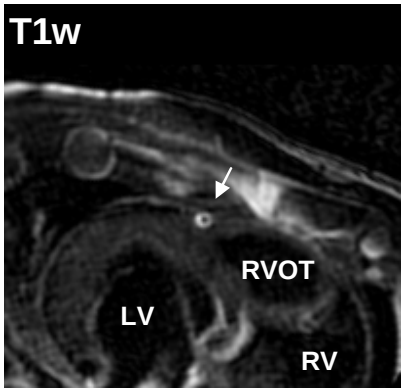

Fig 3. T1-weighted (T1w) inversion recovery image. The inversion time was selected to null the blood signal. The LAD vessel wall appears bright (solid arrow).

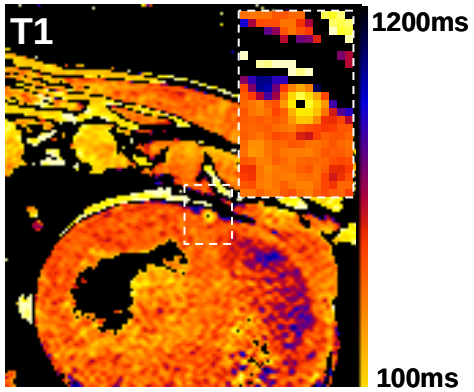

Fig 4. Color-coded T1 map. Significant shortening of T1 is observed in the RCA vessel wall (dotted box) as a result of the local accumulation of elastin-targeted contrast agent. Good blood suppression is achieved.