Determination of the myocardial extracellular volume using an ultra-fast T1 quantification sequence: implications for differentiation of myocardial damage

Daniel Gensler[1,2], Philipp Mörchel[2], Peter M. Jakob[2,3], and Peter Nordbeck[1]

[1]*Department of Internal Medicine I - Cardiology, University Hospital Würzburg, Würzburg, Bavaria, Germany,* [2]*Research Center Magnetic-Resonance-Bavaria, Würzburg, Bavaria, Germany,* [3]*Experimental Physics 5, University of Würzburg, Würzburg, Bavaria, Germany*

Introduction: Late gadolinium enhanced (LGE) cardiovascular magnetic resonance (CMR) is the clinical gold-standard for the visualization of myocardial viability and impairment due to various diseases such as myocardial infarction or fibrosis in non-ischemic cardiomyopathies[1]. However, despite its high sensitivity, LGE CMR has only very limited capabilities for quantitative measurements of slight abnormalities in the myocardium, or the differentiation of acute from chronic myocardial damage. Several basic and clinical studies have shown that cardiac T1 measurements can also be used to acquire diverse morphological and functional information[2,3]. Recent studies particularly focused on new methods to determine the myocardial extracellular volume (ECV) using a capable T1-mapping sequence, e.g. MOLLI as shown by Ugander et al[4]. However, clinical applicability and impact might be hampered due to technical restraints such as temporal and spatial resolution. In the current work an ultra-fast radial T1-mapping sequence was developed and tested for its potential in quantification of the ECV in patients with myocardial infarction. The main goal was to visualize and potentially quantify differences between chronic and acute infarction.

Methods: All measurements were performed on a 1.5 T whole-body imaging system. For T1-mapping a triggered radial single-shot inversion recovery sequence (TRASSI) was used[5]. The TRASSI sequence consists of multiple radial imaging blocks, starting with a certain trigger delay after the corresponding R-waves. Before the first imaging block, a non-selective adiabatic 180° inversion pulse is applied. The radial imaging blocks are acquired with a golden-ratio-based[6] trajectory profile. Images were reconstructed using a modified KWIC-filter[7] to generate a series of several gradient echo images with varying inversion times. For data analysis a special fitting algorithm was implemented that simulates the pulse sequence with the known timings and thus allows the calculation of the correct T1 relaxation times[8].

Ten patients (7 men, 47 - 76 years, 77 - 120 kg) with chronic respectively acute myocardial infarction were investigated with the implemented TRASSI pulse sequence. For visualization of myocardial viability and for determination of the ECV all subjects received an intravenous application of 0.15 mmol/kg CA (Magnograf, Matotrast, Jena, Germany) and T1-maps were acquired before and after contrast agent injection. The ECV was than calculated by the following equation[4]:

$$ECV = \frac{\left(\frac{1}{T1_{Myo,Post-CA}} - \frac{1}{T1_{Myo,Pre-CA}}\right) \cdot (1 - hematocrit)}{\frac{1}{T1_{Blood,Post-CA}} - \frac{1}{T1_{Blood,Pre-CA}}}$$

The data acquisition was performed in end-expiration breath holds, each acquisition with duration of less than 7 s. Sequence parameters were: FOV = 300 x 300 mm², TR = 4.06 ms, TE = 1.86 ms, FA = 7°, slice thickness = 8 mm, reconstructed in-plane imaging resolution = 1.17 x 1.17 mm².

Results: In all ten patients T1-mapping and ECV-determination was successfully realized in high spatial resolution without any motion artifacts using the TRASSI sequence. Figure 1 shows the LGE images and ECV-maps from three patients with chronic and/or acute myocardial infarction. Figure 1a shows the exemplary LGE image and ECV-map from a patient with chronic myocardial infarction. Figure 1b shows the results from a patient shortly (6 days) after acute myocardial infarction and reperfusion. Figure 1c depicts the LGE image and ECV-map from a patient with chronic and acute myocardial infarction. Apparently, the LGE-images clearly revealed spatial myocardial damage in all three patients but did not allow for a clear distinction between the different levels of infarction. In contrast, the ECV-maps allowed for a differentiation between the chronic and acute myocardial infarction areas.

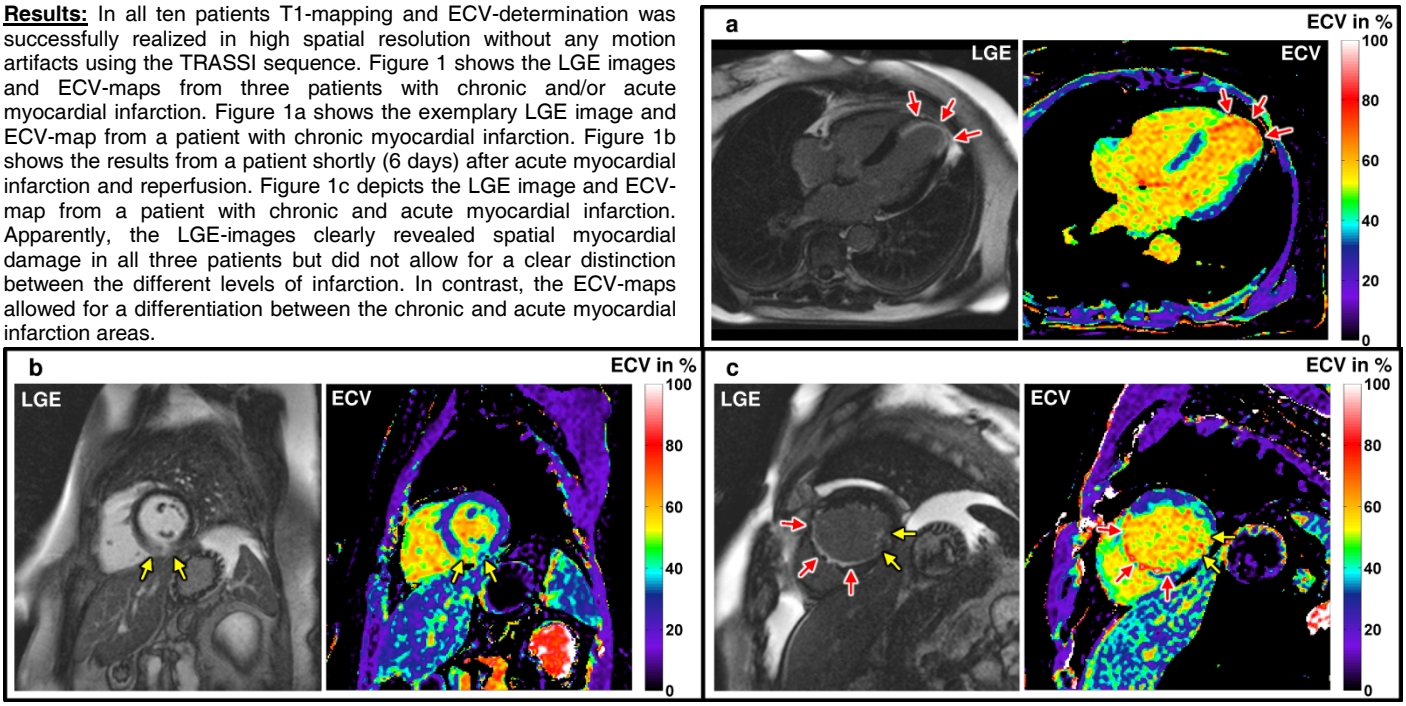

Fig. 1) *LGE-images and ECV-maps from three patients with chronic and/or acute myocardial infarction. Red arrows indicate chronic, yellow arrows indicate acute infarcted areas.* **a)** *Patient with chronic myocardial infarction (4-chamber long axis view). The mean ECV of the healthy myocardium was determined to 29.1 %. The mean ECV of the ischemic area is 67.4 %.* **b)** *Patient with subacute myocardial infarction and reperfusion (mid-ventricular short axis view). The mean ECV of the healthy myocardium was determined to 23.1 %. The mean ECV of the ischemic area is 46.3 %.* **c)** *Patient with chronic and acute myocardial infarction (mid-ventricular short axis view). The mean ECV of the healthy myocardium was determined to 27.5 %. Mean ECV-values were 72.9 % in chronic and 54.6 % in the acute infarcted myocardium.*

Discussion and Conclusion: Despite the high sensitivity of LGE CMR, its limited specificity to differentiate between various types of cardiac diseases make additional subsidiary imaging techniques desirable in clinical routine. Due to its short acquisition time and exceptional robustness to imaging artifacts, T1-mapping using the presented TRASSI sequence enables complimentary information which can be used for quantitative measurements. The presented small preliminary study shows the capability of TRASSI to determine the myocardial extracellular volume in high spatial resolution even in very sick patients with limited reclining and breath-hold capabilities.

References:

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