Motion Corrected Model-based Acceleration of Parameter Mapping (MOCO-MAP) for Improved Late Gd Enhancement Imaging in Cardiac MRI

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Target audience: Scientists and clinicians interested in fast cardiac magnetic resonance imaging (CMR).

Purpose: Late Gd enhancement imaging (LGE) is the gold standard for assessing myocardial infarction [1]. LGE images are typically acquired in a segmented fashion after an inversion recovery (IR) preparation, and the desired contrast with no signal in the vital myocardial tissue has to be adjusted manually by selecting one specific inversion time (TI). If the adjustment of TI is not optimal, however, the differentiation between vital and infarcted tissue is impeded. By combining the iterative model based acceleration of parameter mapping technique (MAP, [2]) with a forward-backward motion correction (abbrev.: MOCO), we developed a method to reconstruct fully sampled 2D images featuring a series of different TI / contrasts out of an IR prepared MR acquisition within a single breath-hold (MOCO-MAP). This enables the determination of T_1*-maps [3] and thus the retrospective selection of an optimized image contrast.

Methods: The method was tested in a healthy volunteer as well as in a patient with a right-ventricular infarction. The study was approved by our institute's ethics committee and written informed consent was obtained from each subject prior to the scan. The investigation was performed on a 3T whole body system (Siemens MAGNETOM Prisma, Erlangen, Germany). After global IR preparation, a 2D radial FLASH pulse sequence with a golden angle increment between subsequent readouts was applied (healthy volunteer: T_R=4.4 ms, T_E=1.8 ms, FOV= 260 × 260 mm^2, resolution=2.3 × 2.3 × 8 mm^3, 3000 projections, 32 receiver coil elements; patient: 12 ml gadoterate meglumine, T_R=3.1 ms, T_E=1.4 ms, FOV=500 × 500 mm^2, resolution=2.8 × 2.8 × 8 mm^3, 3000 projections, 16 receiver coil elements, ECG recording). In a first reconstruction step, a compressed sensing algorithm (FISTA, [4] modified) was applied to obtain a fully sampled dynamic cine image series (Fig. 1). To ensure an unchanging contrast, only projections of late TI values were used for this reconstruction. Next an image registration algorithm [5] was applied to this cine series to determine a transformation from a dynamic to a static series, and vice versa. Finally, the MAP algorithm, as described in [2], was adjusted as follows to enable the reconstruction of moving objects: Within each iteration, an image registration step was inserted to freeze any motion before applying the through-time exponential fit of the data. Before ensuring data consistency, this registration was inverted again. To stabilize the reconstruction, the consistency step of the MAP reconstruction was performed with k-spaces consisting of eight projections, resulting in a temporal footprint of 35ms for the healthy volunteer and 25ms for the patient.

Fig. 1

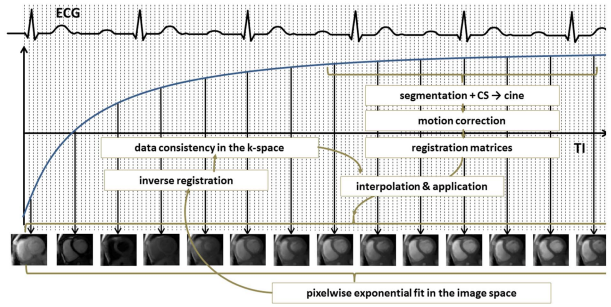

Fig. 1: Schematic over-view of the MOCO-MAP procedure.

Results: Figure 2 shows a short-axis view of a single mid-ventricular slice in the healthy volunteer. The application of the proposed method yields a series of real time images after an IR preparation with high temporal and spatial resolution. Undersampling artifacts were almost perfectly removed by the reconstruction. The same image quality was achieved in the long axis view of the heart in the patient with right-ventricular infarction (Fig. 4). The series allows for the selection of a frame with optimized contrast for the evaluation of potentially infarcted myocardium.

Fig. 2

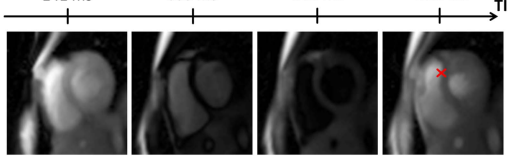

Fig. 3

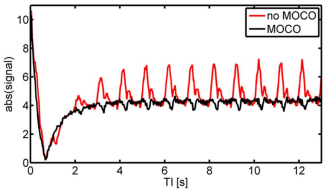

Fig. 4

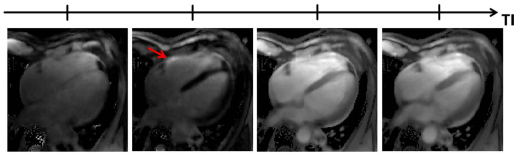

Fig. 2: Results of the acquisition in a healthy volunteer for exemplary TI values. Fig. 3 shows the courses of the pixel depicted by a red cross in Fig. 2 both for the registered and the unregistered series. Fig. 4 presents the results of MOCO-MAP for a long-axis view in a patient with a right-ventricular infarction (see red arrow).

Discussion & Conclusion: Our study demonstrates that MAP can be applied for reconstructing image series of moving organs by adding a forward-backward motion correction. In addition to an improved depiction of LGE, this method allows for both displaying real time images and evaluating wall motion in CINE series with freely selectable contrast after the inversion pulse. However, MOCO-MAP still has to be validated against established methods in larger collectives of patients with relevant heart disease.

References: [1] Kim et al., New Engl J Med 2000;343:1445-1453, [2] Tran-Gia et al., Magn Reson Med 2013;70:1524-34, [3] Stalder et al., ISMRM 2014;431, [4] Beck et al., SIIMS 2009;2:183-202, [5] Myronenko et al. IEEE T Med Imaging 2010;29:1882-91.