T1-mapping based synthetic phase-sensitive inversion recovery imaging for the accurate quantification of myocardial late gadolinium enhancement

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Target audience: Clinicians involved in application of quantitative late gadolinium enhancement imaging

Purpose: The T1-based synthetic inversion recovery (IR) technology was originally developed for a modified look-locker IR (MOLLI) prototype to support image registration in the implementation of a motion correction algorithm.[1] Such synthetic IR images can be retrospectively generated at any theoretical inversion time (TI) based on the voxel by voxel T1 values. In this study we aimed to compare the accuracy of late gadolinium enhancement (LGE) quantification between the conventional phase sensitive IR (PSIR) technique and the synthetic PSIR images generated by an in-house developed application.

Methods: The Institutional Review Board approved the study protocol. Consecutive patients (n=32) underwent a clinically indicated contrast enhanced cardiovascular MRI at our institution using a 1.5T MRI scanner (MAGNETOM Avanto, Siemens Healthcare, Erlangen, Germany). Imaging was performed during breath-hold at end-expiration. LGE (single-shot IR, field of view (FOV) 300-360mm, slice thickness 8mm, image reconstruction matrix 256×256, echo and repetition time (TE/TR) 3.9/2.6ms, and flip angle 25°) and investigational prototype MOLLI-based T1 mapping[2] (MOLLI acquisition scheme 4(1)3(1)2, single-shot steady-state free precession readout, TE/TR 1.1/2.6ms, and flip angle 35°) acquisitions were performed 12-15 minutes after the administration of 0.1mmol/kg gadobenate-dimeglumine (MultiHance, Bracco, Princeton, NJ). T1 mapping was performed immediately after the conventional LGE imaging. Slice position and orientation of one short-axis view (involving the hyperenhancement if any) was copied from the conventional LGE acquisition. Respiratory motion correction implemented in the image reconstruction was applied as described previously.[1] Based on the motion corrected MOLLI data sets (**Figure 1A**), T1 maps (**Figure 1B**) were generated by applying a non-linear three parameter least-square curve fitting inline. Further image analysis was performed using Mass Research Software (Leiden University Medical Center, Leiden, The Netherlands). Using the in-house developed synthetic IR image calculator integrated in the Mass Research Software, synthetic PSIR images (**Figure 1C**) were computed between 200 and 400ms interval with a 10ms increment using the following equation: $M(TI) = A - B \times \exp(-TI/T1)$, where M(TI) is the SI at a given TI, A=1 and B=2 since the efficiency of the inversion pulse in the prototype MOLLI pulse sequence is 0.975, and a correction factor is applied in the T1 mapping to account for the 1/0.975 error.[3] The synthetic PSIR image with the very same TI used for the conventional imaging was analyzed. LGE was quantified by two independent readers applying a binary threshold algorithm using five standard deviations above the average SI of the normal myocardium. This area was then expressed as the percentage of the total myocardium in the particular slice (infarct fraction). Student's t-test and Bland-Altman analysis were used for statistical evaluation.

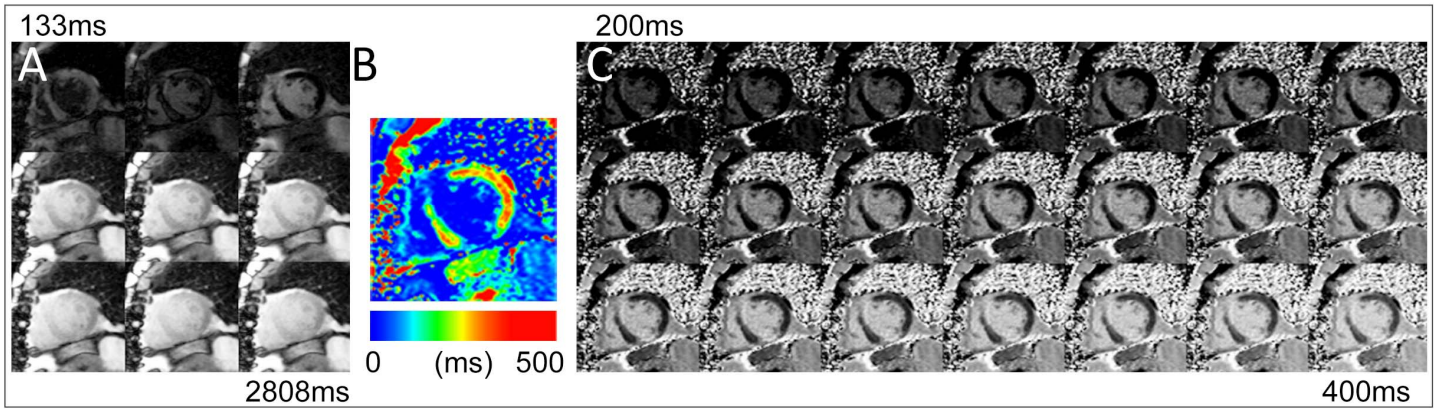

Figure 1 – Representative image sets from a patient with antero-septal and inferior myocardial infarction. **A**, MOLLI data set acquired with nine different TIs. **B**, Color-coded T1 map based on A. **C**, synthetic PSIR image set from 200 to 400ms generated from B.

Results: LGE was observed in 11 (34.3%) patients. LGE pattern was consistent with myocardial infarction in all cases. Representative image sets are shown in **Figure 1**. The infarct fraction measured by conventional and synthetic PSIR techniques was 21.4±7.2 and 20.7±7.4%, respectively, and statistically identical (p=0.227). Inter-observer studies revealed excellent agreement between the two readers (κ>0.81). Bland-Altman analysis revealed excellent agreement between the conventional and the synthetic PSIR techniques with 0.7% average bias and -2.8 and 4.2% limits of agreement.

Discussion: In this project we have shown the feasibility of LGE quantification using synthetic PSIR images generated from T1 maps. Based on Bland-Altman analysis, synthetic PSIR images provide the same accuracy for quantifying infarct fraction as the conventional PSIR images used in clinical practice. With the increasing acceptance and availability of T1 mapping, the need for conventional PSIR images could be omitted in the future, resulting in a significant reduction in scanner table time. In addition, the same technique is available for the generation of magnitude IR imaging by calculating the absolute value of the magnetization at a theoretical TI. Such technique allows for the retrospective review of the entire TI range, and the selection of the most optimal TI, which would eliminate the need to optimize the magnitude IR acquisition (TI scout, TI readjustment) without additional scanning time.

Conclusions: Synthetic PSIR images can be derived from the T1 maps without adding additional scanning time. Synthetic PSIR/IR images provide a feasible way to evaluate LGE in patients with myocardial infarction, which might eliminate the need for the conventional acquisitions once T1 mapping is integrated in the clinical routine. Such images will still be beneficial for physicians unfamiliar with novel myocardial mapping techniques.

References:

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