Accuracy and precision of myocardial T₁ mapping with MOLLI and ShMOLLI at 1.5T and 3.0T: a phantom study

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Background
Previous studies have demonstrated that an increase in extracellular volume measured on MRI is directly proportionate to myocardial fibrosis. Myocardial extracellular volume is proportionate to partition coefficient (λ) and extracellular volume = λ x (1-hematocrit). λ can be measured by assessing the T₁ relaxation time before and after injection of contrast medium. The goal of this study is to assess the accuracy and precision of several T₁ mapping sequences using a phantom at 1.5 and 3.0T.

Methods
Experiments were performed on two magnets; a 1.5T magnet (Avanto, Siemens) and on a 3.0T magnet (Verio, Siemens) with a 32 phased array cardiovascular coil. phantoms were built using 15 separate tubes to produce similar T₁ and T₂ values of myocardium and blood before and after gadolinium administration. All sequences were tested with an ECG simulation at heart rates 40, 60, 90, 120. To assess the standard T₁ value for each tube, we used a tube spin echo inversion-recovery sequence (TR/TE = 13000/18 ms, with 17 inversion times between 30-9000 ms turbo factor = 7). The T₁ value was assessed using an ECG gated single shot modified Look Locker inversion recovery (MOLLI) and several different schemes of Short MOLLI: at 1.5T (α:35°, 5-2 and 4-3-2 sampling schemes; with a pause of 3 HB) and at 3.0T (α:35° and 20°; 5-2 and 4-3-2 sampling schemes; pause: 3 and 4 HB). We calculated errors in the MOLLI T₁ estimation according to Error T₁ (%) = ((T₁MOLLI-T₁reference)/T₁reference)x100. We assessed the effect of T₂ value, T₁ value, heart rate and MOLLI schemes on T₁ errors.

Results
At 1.5 and 3.0T, the under estimation of T₁ with MOLLI sequence was important, highly dependent on heart rate and increased significantly from 40 to 120 bpm. Using ShMOLLI sequences, the effect of heart rates was lower than 1% at 1.5T (Figure 1), and was not dependent on heart rate at 3.0T (Figure 2). The underestimation of T₁ was present in shorter T₂ phantoms and less in longer T₂ phantoms. The effect of T₂ on T₁ error was predominant at low heart rates. Underestimation of T₁ was predominant in higher T₁ and at higher heart rate. We measured a significant relationship between the T₁ value and % of T₁ error. At 3.0T, acquisitions with a flip angle at 20° showed less T₁ underestimation compared with 35°. The addition of one heart beat pause showed less underestimation for longer T₁ with the 5-2 schemes but did not change the results significantly for short T₁ values.

Conclusions
ShMOLLI sequences provide an accurate assessment of T₁ at 1.5T and 3.0T.

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Figure 1 Showing the linear regression between % T1 error of the different sequences compared to reference T1 value at each heart rate tested at 1.5T.

Figure 2 Showing the linear regression between % T1 error of the different sequences compared to reference T1 value at each heart rate tested at 3.0T.
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