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T_2-dependent errors in MOLLI T_1 values: simulations, phantoms, and in-vivo studies

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Background

Diffuse myocardial fibrosis occurs in various cardiomyopathies and can be indirectly assessed with blood and myocardial T_1 mapping at baseline and after gadolinium administration. The widely used MOdified Look-Locker Inversion-recovery (MOLLI) [1] sequence is known to underestimate myocardial T_1 at higher heart rates, but its dependence on T_2 has not been explored. We investigate MOLLI's T_1 accuracy in phantoms and confirm with simulations and in-vivo studies. T_1 values are further compared with a saturation-recovery T_1 mapping sequence [2].

Methods

Phantoms

14 $NiCl_2$ agarose phantoms with a broad range of T_1 and T_2 values were imaged with a gold-standard inversion-recovery spin-echo (IR-SE) sequence, MOLLI, and a new SAturation-recovery single-SHot Acquisition (SASHA) technique (Siemens Avanto 1.5T). IR-SE: 16 TIs 100-5000ms, TE=11ms, TR>5s, 90° flip. MOLLI: 2 inversion sets of 3 and 5 images, 75% partial Fourier, TImin=110ms with 80ms increment, 35° flip, TE/TR=1.3/2.9ms, simulated HR=60bpm. SASHA: single-shot SSFP images from 10 consecutive heartbeats with incremented TI spanning the RR interval in the last 9 images (no saturation in the first image), 70° flip, TE/TR=1.3/2.6ms, full k-space, simulated HR=60bpm. T_2: spin-echo (SE) with 7 TEs 11-200ms. Simulations: Bloch equation simulations of MOLLI and SASHA were performed in MATLAB using actual acquisition and physiology parameters and SE measured T_1 and T_2 values.

In-Vivo

For 10 healthy volunteers (5 male, 28.8±6.6yrs), blood and myocardial T_1s were measured using MOLLI and SASHA (parameters as above) in a mid-ventricular short-axis slice at baseline and 20 minutes following 0.1mmol/kg Magnevist.

Results

In blood-like phantoms with long T_2 (179-196ms), SASHA and MOLLI T_1s agree well with IR-SE (0.7±0.5% and 2.2±1.8% absolute difference respectively), while shorter T_2 (46-76ms) tissue-like phantoms have greater underestimation with MOLLI (8.4±3.5%) than SASHA (0.9±0.6%) (Fig. 1). MOLLI simulations predict underestimated T_1s, with 1.3±0.9% absolute difference from observed values (vertical lines, Fig. 1). SASHA simulations also agree well with observations (0.8±0.5%, not shown). In healthy volunteers (63.3±8.4bpm), MOLLI T_1s also show greater underestimation compared to SASHA in tissue than blood, although the difference is larger than observed in phantoms or predicted by simulations in all cases (Table 1).

Conclusions

MOLLI significantly underestimates T_1s in shorter T_2 tissue-like phantoms but less so in longer T_2 blood-like phantoms, as predicted by simulations. Similar trends were observed in-vivo with MOLLI, although with greater T_1 underestimation (compared to SASHA) than predicted. SASHA had good agreement with IR-SE T_1 phantom measurements and simulations and can be acquired in less time than MOLLI.

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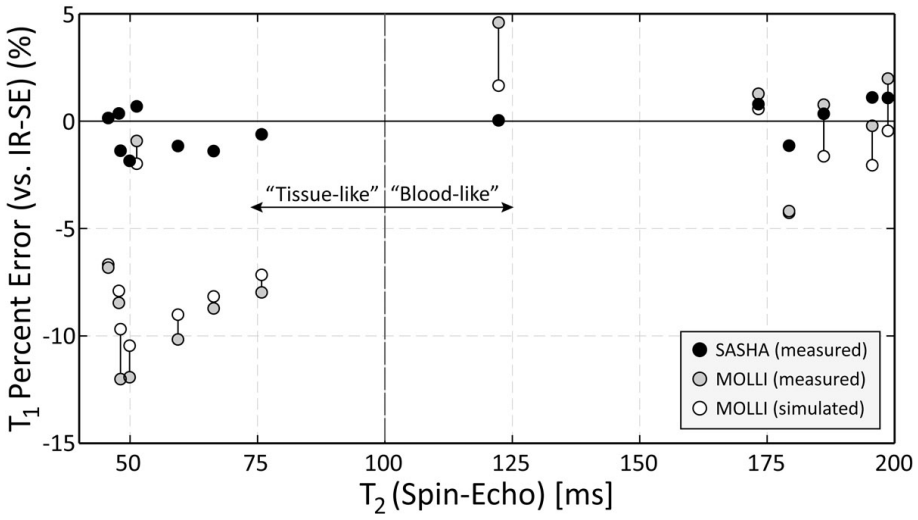

Figure 1 Error in MOLLI and SASHA T_1 values compared to gold standard inversion-recovery spin-echo (IR-SE) in "tissue-like" phantoms (T_1s 339-1145ms) and "blood-like" phantoms (T_1s 275-1452ms). A Bloch equation simulation of MOLLI using actual acquisition and physiology timing parameters is also shown, with the difference between simulated and actual results indicated with a vertical line for each phantom.

Table 1 Comparison of MOLLI and SASHA T_1 values in 10 healthy volunteers prior to and 20 minutes following 0.1 mmol/kg Magnevist. All comparisons between MOLLI and SASHA are significant (p<0.01, two-tailed, paired Student's t-test).

T_1 [ms]	Myocardium (mean±std)		Blood (mean±std)	
	Baseline	Post Gd (20 min)	Baseline	Post Gd (20 min)
MOLLI	935.5±24.9	614.4±33.8	1514.1 ±107.5	524.9±55.2
SASHA	1175.2 ±27.6	752.9±48.2	1687.4±85.8	542.6±56.3

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