# Saturation Recovery Modified Look Locker (S-MOLLI) for Cardiac T1 Mapping

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## Introduction

Cardiac T1 mapping techniques, such as modified Look Locker inversion recovery ("MOLLI", [1]) offers valuable clinical information in myocardial diseases [2]. MOLLI interrogates the inversion recovery curve over a series of RR intervals. This yields an apparent relaxation time, T1*, which can be corrected towards the true T1 using the exponential fit parameters [3]. This also provides a stable T1 measurement, which is invariant of the sequence parameters and the RR interval. However, a number of "empty" RR intervals are needed prior to a new re-inversion pulse to allow for magnetization recovery. This prolongs the duration of the breath hold considerably and may not be tolerated by all patients. Saturation recovery overcomes this need, but does not allow to correct from T1* towards T1 per se. Therefore, an alternative saturation recovery sequence including T1 correction, S-MOLLI, is investigated in phantom studies and first *in vivo* experiments.

## Methods

Experiments were conducted on a clinical 1.5T MR scanner (Philips Healthcare) using a 5 element cardiac coil array. A cylindrical phantom (EUROSPIN TEST OBJECT 5, Diagnostic Sonar) comprising 12 samples with different T1 was employed, and 5 different heart rates ranging from 60bpm to 120bpm were simulated. MR sequences: (1) Conventional MOLLI [1] protocol, FOV 300 x 280mm, resolution 2.0 x 2.0mm², 10mm slice thickness, balanced SSFP, α=45°, 2 inversion delays, 3 images after first inversion, 5 images after second inversion, 4 empty RR intervals between re-inversion, total scan time: 12 RR intervals; (2) S-MOLLI sequence with WET-saturation pulse instead of inversion, otherwise identical scan parameters, no empty RR intervals, one additional image without presaturation (M0) acquired at the beginning of the scan, total scan time 9 RR intervals. T1* was obtained from an exponential fit to the measured data, and T1 was obtained using a correction factor involving the M0 image:

$$M = A - B \cdot e^{-\frac{ts}{T_1^*}} \text{ and } T_1 = \frac{M_0}{A} \cdot T_1^* \qquad \text{(Eq. 1 and 2)}$$

A reference T1 measurement with an existing sequence [4] was performed for comparison. Furthermore, first *in vivo* experiments were conducted in 5 healthy adults.

## Results

A plot of the measured and corrected T1 values (mean ± standard deviation over simulated heart rates) over the references values are shown for the MOLLI and S-MOLLI in Fig. 1. Selected *in vivo* results are shown in Fig. 2 [a] and [b], respectively.

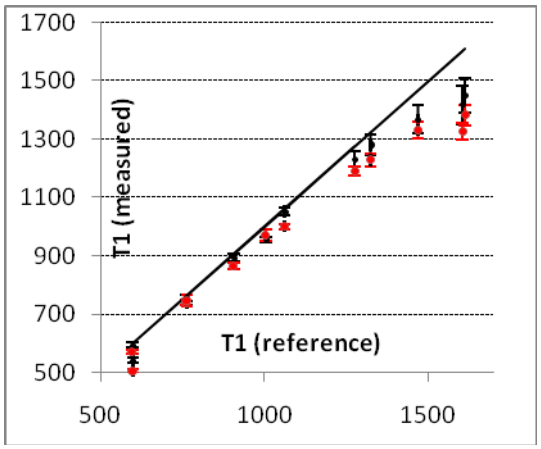


**Fig. 1** Plot of measured T1 over reference values. Black=MOLLI, red = S-MOLLI. All values are shown as mean ± std dev over different heart rates (60-120bmp)

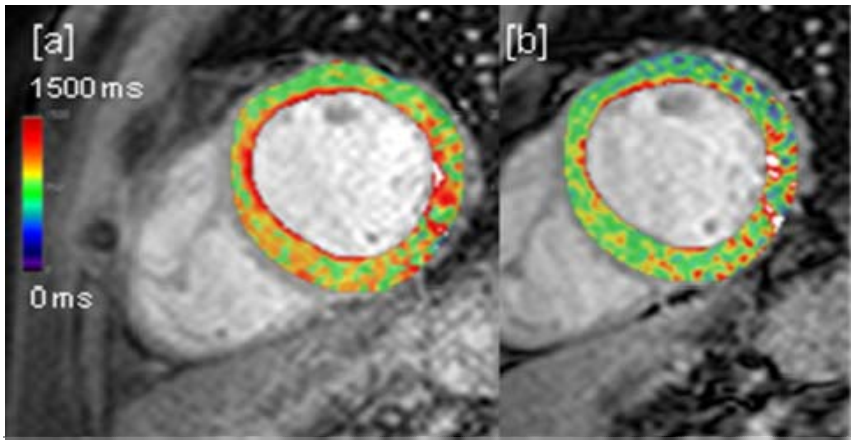


**Fig. 2** Overlay of anatomy (mid-ventricular short axis view) and color-coded T1 maps acquired with MOLLI [a], and S-MOLLI [b]. A good agreement of T1 was obtained with both methods, where T1 noise was slightly higher with S-MOLLI.

## Discussion and conclusion

After respective T1 correction, the *in vitro* values measured with MOLLI and S-MOLLI are in good agreement. There is a slight but consistent underestimation of T1 with both methods. The variability of T1 with the RR interval (error bars) is slightly lower with S-MOLLI, which is beneficial for a comparison of data obtained at different heart rates. The *in vivo* T1 maps obtained with MOLLI and S-MOLLI are in good agreement (with slightly elevated noise with S-MOLLI), where the resulting scan time is considerably shorter with S-MOLLI (9 RR versus 12 RR intervals), which may be beneficial for patients with poor breath holding capabilities. In conclusion, S-MOLLI offers shorter breath hold durations and invariant T1 values over a wide range of RR intervals. This would facilitate a comparison of data acquired at different cardiac heart rates, e.g. in follow up examinations or during rest and stress.

**References:**

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