Multi-Slice Saturation-Recovery Look-Locker Method for Rapid T1 Mapping of Mouse Myocardium

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Introduction

Quantitative assessment of physiological parameters using dynamic contrast-enhanced MRI (DCE-MRI) requires accurate mapping of T_1 at high temporal resolution. The Look-Locker method has been used for robust and relatively fast *in vivo* T_1 measurement. However, it generally requires a repetition time (TR) that is 5 times the T_1 for complete relaxation of longitudinal magnetization (M_z) in each repetition. Previously, a saturation-recovery Look-Locker (SRLL) method was developed in our lab to eliminate the requirement of long TR. This method allowed the acquisition of a single slice T_1 map of mouse myocardium within 3 min[1]. In the current study, a multi-slice saturation recovery Look-Locker (MSRLL) method was developed for complete T_1 mapping of the whole mouse heart at no additional time cost.

Methods

MSRLL Protocol The MSRLL sequence is shown in Fig. 1. To eliminate the requirement of long TR, an ECG-triggered saturation pulse is applied at the beginning of each acquisition cycle, followed by 10 sequential multi-slice FLASH acquisitions separated by interval τ. For *in vivo* studies, acquisition of FLASH images was triggered by ECG at every two heart beats, equivalent to a τ of 2 R-R intervals. To minimize the effects of cardiac motion, a trigger delay of 90 ms was used such that all the images were acquired at late diastole.

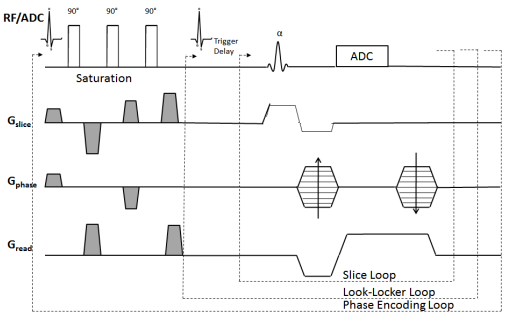

Fig. 1. MSRLL sequence.

Validation Studies All MRI studies were performed on a horizontal 7.0T Bruker scanner (Bruker Biospec, Germany) with a 35 mm inner diameter volume coil. The MSRLL method was first validated *in vitro* using a multi-compartment phantom with $MnCl_2$ solutions ranging from 30 μM to 1000 μM and sealed in 1 mL centrifuge tubes. T_1 maps of 5 slices were acquired and compared with those acquired with single-slice SRLL.

For *in vivo* validation, two 4-month-old C57BL/6J mice were anesthetized with 1% isoflurane and their heart rates were maintained at ~500 beats/min with 0.8–1.8% isoflurane. T_1 maps of three short-axis slices were acquired with during a period of 23.6 ms at late-diastole. Imaging parameters were: flip angle, 10°; TE, 3.5 ms; FOV, 2.5×2.5 cm^2; matrix size, 128x64.

Results

T_1-weighted images of a phantom acquired at 2τ, 4τ and 10τ after the saturation pulses are shown in Fig. 2a-c. The continuous increase of the image intensity reflects the recovery of longitudinal magnetization. Total acquisition time was 2 minutes and 40 seconds. A representative T_1 map is shown in Fig. 2d. Comparison of the average T_1 values in each compartment showed no difference among all 5 slices and those acquired with single-slice SRLL method (Fig. 2e).

T_1-weighted images of a mouse heart acquired at 2τ, 4τ and 10τ after the saturation pulses are shown in Fig. 3a-c. The average acquisition time was also about 2 minutes and 40 seconds. Fig. 3d shows a T_1 map of the midventricular slice. Average myocardial T_1 values in all three slices showed good agreement with those obtained with single-slice SRLL method (Fig. 3e).

Conclusion

An ECG-triggered, multi-slice saturation-recovery Look-Locker method was developed for fast cardiac T_1 in mice. Validation studies performed both *in vitro* and *in vitro* showed strong agreement between the current method and the previously validated single-slice Look-Locker method.

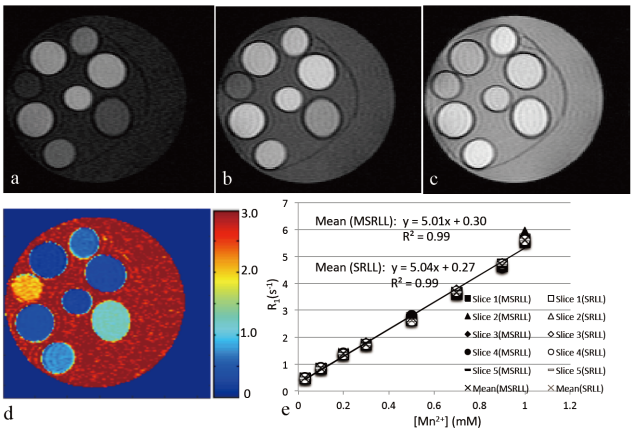

Figure 2. Phantom validation. **a-c.** T_1-weighted images acquired at 2τ, 4τ, and 10τ, respectively. **d**. T_1 map of slice 1. **e**. Average T_1 values in 5 slices and averaged Mn relaxivity curves by MSRLL and single-slice SRLL.

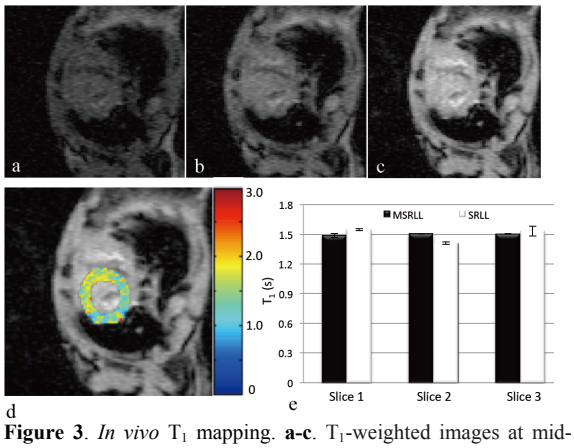

Figure 3. *In vivo* T_1 mapping. **a-c**. T_1-weighted images at mid-ventricle acquired at 2τ, 4τ, and 10τ, respectively. **d**. T_1 map of the mid-ventricular slice. **e**. Comparison of myocardial T_1 values measured by MSRLL and SRLL.