Myocardial T_1 Mapping Comparing SMART$_1$Map and MOLLI: Clinical Experience at 3T

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Target Audience: Those with an interest in cardiac magnetic resonance (CMR) tissue characterization

Purpose: Recent advances in CMR allow for quantitative characterization of myocardial T_1 signal. By assessing T_1 signal at multiple time points, a T_1 recovery curve can be generated and compared to normative values. Various cardiac diseases predictably alter myocardial T_1 values in a fashion that correlates with the degree of fibrosis seen on endomyocardial biopsy[1]. Assessment of cardiac T_1 maps permits serial evaluation of myocardial disease in a non-invasive manner, potentially sparing the need for biopsy and assisting in therapeutic planning[2]. Look-Locker (LL) approaches such as MOLLI (MOdified Look-Locker Inversion recovery) are currently employed in cardiac T_1 mapping, as they enable acquisition of high signal-to-noise images in a breath-held scan. However, MOLLI is susceptible to heart rate variability, does not directly measure T_1 and instead yields an "apparent" T_1 (T_1*). Because T_1* is always shorter than true T_1, additional correction methods must be applied in order to derive an estimate of true T_1. SMART$_1$Map (Saturation Method using Adaptive Recovery Times for cardiac T_1 Mapping) is an emerging sequence that directly measures true T_1[3], in addition to being able to account for heart rate variation. The **purpose of this study** was to prospectively assess the variability and repeatability of pre-contrast SMART$_1$Map in quantification of left ventricular (LV) myocardial ("native") T_1 values in patients referred for clinical CMR at 3T, using MOLLI as a standard of comparison. *Hypothesis:* SMART$_1$Map provides improved variability and repeatability when compared to MOLLI at 3T.

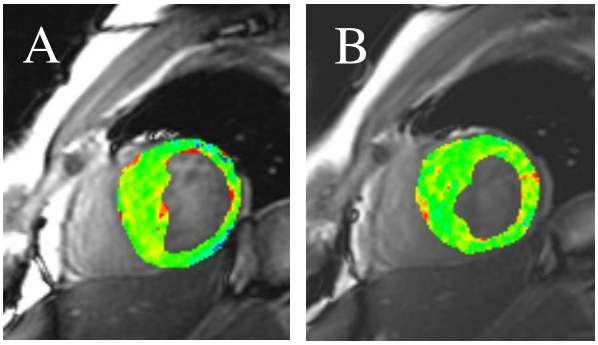

Figure 1: Short-axis pre-contrast (A) MOLLI with T_1* correction and (B) SMART$_1$Map in a 42 year-old male referred for CMR for hypertrophic cardiomyopathy.

Materials and Methods:

Subjects: Twelve patients (9 males, age 60.1±10.9 and 3 females, age 59.0±14.7) having a clinical indication for CMR were prospectively enrolled according to an IRB-approved and HIPAA-compliant protocol. Indications for CMR included: myocardial infarction and viability assessment (3 patients), hypertrophic cardiomyopathy (2 patients), dilated cardiomyopathy (2 patients), sarcoidosis (2 patients), atrial fibrillation pre-ablation evaluation (2 patients) and amyloidosis (1 patient). CMR was performed on a clinical 3T MRI scanner (Discovery MR 750w, GE Healthcare, Waukesha, WI). T_1 mapping was performed prior to the administration of intravenous gadolinium-based contrast material. Three short-axis slices were acquired through the basal, mid and apical left ventricle **(Figure 1)**.

MOLLI parameters: FOV = 35-37x35-37cm (50x50cm in one patient), Matrix = 192x128, TE = 1.8-2.0ms, TR = 3.9-4.3ms, Flip angle = 65 deg, Bandwidth = 93.7kHz, NSA = 0.5, Slice thickness = 7-8mm (15mm in one patient), Slice spacing = 20-23mm (15mm in one patient). Data was acquired with a 3-3-5 sampling pattern (11 TIs per slice) with initial TI ranging from 292-454ms. *SMART$_1$Map parameters:* FOV = 35-37x35-37cm (50x50cm in one patient), Matrix = 192x128, TE = 1.8-2.0ms, TR = 3.9-4.3ms, Flip angle = 65 deg, Bandwidth = 93.7kHz, NSA = 0.5, Slice thickness = 7-8mm (15mm in one patient), Slice spacing = 20-23mm (15mm in one patient). Data was sampled in a 1-1-1-2-3-4 pattern (7 saturation delay times per slice, dependent on patient heart rate). MOLLI T1* maps were corrected using the method published by Deichmann and Haase[4]. SMART$_1$Map acquires true T_1; therefore, no correction of these images was necessary.

Analysis: Images were anonymized and subsequently analyzed by two observers within Osirix (Pixmeo, Geneva, Switzerland). Regions of interest (ROI) having areas of approximately 1.0cm^2 were drawn in 16 AHA cardiac segments (segment 17 was excluded from analysis)[5]. Each ROI yielded a mean T_1 time for its respective cardiac segment. Images were de-identified and differences in mean T_1 for each segment between MOLLI and SMART$_1$Map were analyzed by calculating mean, standard deviation and variance. Data from one patient was excluded due to excessive image noise. Paired t-tests were used to determine statistical significance of differences between MOLLI and SMART$_1$Map for each observer. Variability and repeatability analysis was performed using the intraclass correlation coefficient, coefficient of variability and Bland-Altman analysis.

Sequence	ICC	Coefficient of Variability (%)		95% Repeatability Coefficient (Bland-Altman) (%)
		Obs #1	Obs #2	
MOLLI	0.71	14.2	14.6	43.6
SMART$_1$Map	0.91	12.4	12.6	15.6

Table 1: Intraclass correlation coefficients, coefficients of variability and Bland-Altman 95% repeatability coefficients for MOLLI and SMART$_1$Map.

Results: MOLLI myocardial T_1 times for observers #1 and #2 were 1633±232ms and 1570±229ms, respectively. SMART$_1$Map myocardial T_1 times for observers #1 and #2 were 1755±217ms and 1798±227, respectively. Differences in the standard deviation between MOLLI and SMART$_1$Map yielded p-values of 0.834 and 0.956 for observers #1 and #2, respectively. Results of variability and repeatability analysis are summarized in **Table 1**. Bland-Altman analysis revealed SMART$_1$Map and MOLLI to have a mean difference of 161ms (95% limits of agreement: -646,969).

Discussion and Conclusion: SMART$_1$Map provides decreased variability in measured myocardial T_1 times when compared to MOLLI, in conjunction with acquiring true T_1 (as opposed to T_1*) and offering improved repeatability. Although differences in standard deviation alone between MOLLI and SMART$_1$Map were not statistically significant, additional measures suggest that SMART$_1$Map is a robust and reliable technique. SMART$_1$Map acquired T_1 times that were on average 161ms longer than MOLLI, an observation that is likely related to the latter's acquisition of T_1*, even after T_1* correction algorithms have been applied[3]. Collectively, these benefits offer improved precision in myocardial T_1 mapping and serve as a stepping-stone for continued advancements in myocardial tissue characterization.

References: [1] Sibley C *et al. Radiology.* 2012 Dec;265(3):724-32. [2] Moon JC *et al. J Cardiovasc Magn Reson.* 2013;15(1):92. [3] Slavin GS, Stainsby JA. *J Cadiovasc Magn Reson.* 2013, 15(Suppl 1):P3. [4] Deichmann R, Haase A. *J Magn Reson.* 1992;96(3):608-612. [5] Cerqueira MD *et al. Circulation* 2002;105:539-42.