Inline Myocardial T2* Mapping with Iterative Robust Fitting

S. Shah[1], H. Xue[2], A. Greiser[3], P. Weale[1], T. He[4], D. N. Firmin[4], D. J. Pennell[4], S. Zühlsdorff[1], and J. Guehring[3]
[1]Siemens Healthcare, Chicago, IL, United States, [2]Siemens Corporate Research, Princeton, NJ, United States, [3]Siemens AG, Erlangen, Germany, [4]Royal Brompton Hospital, London, United Kingdom

Introduction: Myocardial T2* measurement is a valuable tool for non-invasive assessment of iron overload, and is clinically employed for planning and monitoring iron-chelating treatments for transfused thalassemia major patients[1]. Presently, for T2* assessment, dark-blood prepared gradient echo (GRE) images are acquired at multiple echo times (TEs). Thereafter, these images are analyzed within offline software, in which, typically, the septal signal of a full thickness region-of-interest (ROI) is fitted to a monoexponential decay curve to estimate myocardial T2*[2]. The goal of this study was to develop and test a T2* measurement technique with automated inline T2*-map generation. Availability of such a technique on commercial MR systems may further facilitate utilization of such measurements in this patient group.

Methods: An ECG-triggered 2D multi-echo GRE sequence was implemented on a 1.5T MR scanner (MAGNETOM Espree, Siemens AG, Healthcare Sector, Erlangen, Germany) with support for dark-blood preparation (DB-prep)[3]. To generate an inline T2*-map, an integrated image reconstruction performs pixel-wise T2* estimation using a robust fitting technique, in which the signal at each TE is iteratively weighted to reflect its fidelity to monoexponential decay curve. Signal points farther from the ideal relaxation curve are weighted lower, reducing their influence on the fit. The weights of outlier points can be completely zero, eliminating their negative impact on the fit.

In five healthy volunteers, the method was used to acquire short axis images of the heart, accompanied by inline T2*-map computation. Additionally, to compare the accuracy of the proposed robust-fit with a validated method, T2*-maps were retrospectively computed using multi-echo images of 32 patients, which were obtained using a similar DB-prep 2D multi-echo GRE acquisition on a 1.5T scanner (MAGNETOM Sonata). In all cases, a septal ROI was manually drawn to obtain an average T2* value from the T2*-map. Linear regression was employed to statistically compare these average T2* values to the ones obtained using offline analysis within CMRTools:ThalassaemiaTools®.

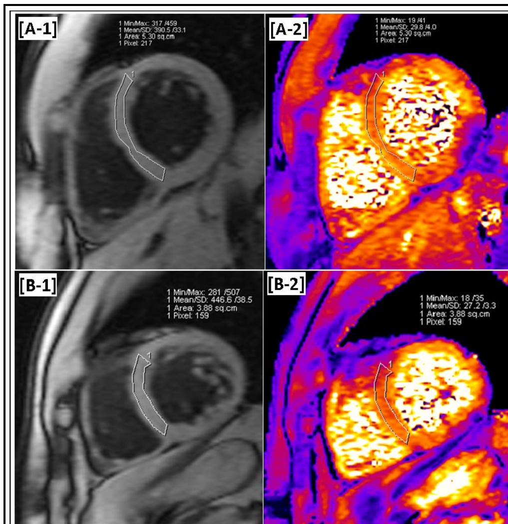

Figure 1: DB-prep GRE images [A-1, B-1] and corresponding T2*-map [A-2, B-2] produced using inline analysis in two healthy volunteers. The contours in these images mark septal regions from which the average T2* value was estimated. The average T2* value within septal regions were 29.8 ± 4.0 ms and 27.2 ± 3.3 ms for these two subjects, which are significantly above T2* < 20 ms range indicating cardiac iron overload.

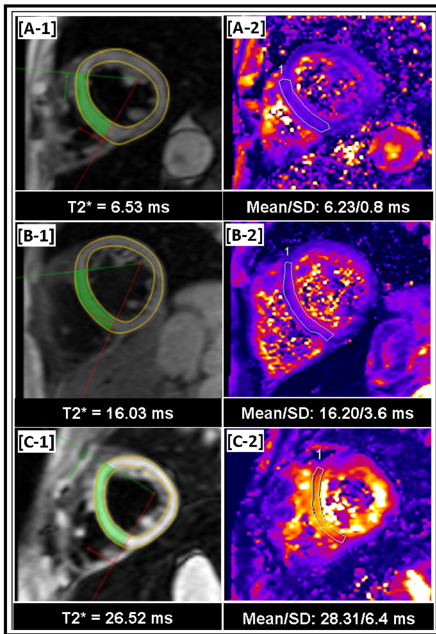

Figure 2: T2* estimates in 3 patients with suspected iron overload. [A-1, B-1, C-1] A DB-prep GRE image showing the region used for T2* estimate within CMRTools. The estimated T2* is listed directly below each image. [A-2, B-2, C-2] Corresponding T2* maps obtained with inline analysis. Average of pixel-wise T2* estimate was obtained from indicated septal region. In all 3 cases, the average value obtained from T2*-map closely matches the one calculated using CMRTools.

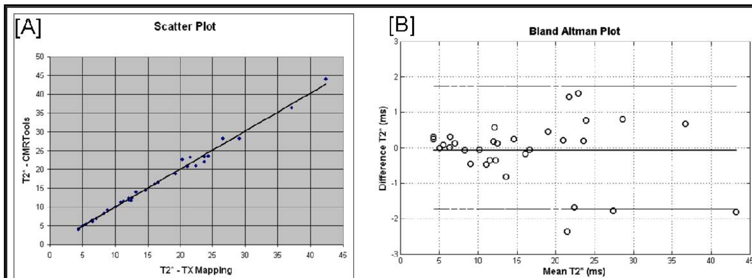

Figure 3: Statistical comparison between CMRTools and inline T2*-maps. 32 patients with suspected iron overload were retrospectively analyzed using both methods. The classification of each patient within severe (T2* < 10ms; 10 patients), mild or moderate (10ms < T2* < 20ms; 11 patients) or no iron overload (T2* > 20ms; 11 patients) group was identical for both methods. [A] shows scatter plot comparing T2* values estimated using CMRTools to those obtained using inline T2*-maps. Linear Regression: slope=1.01, intercept=-0.12 and R2=0.996. [B] is a Bland-Altman plot comparing T2* estimates using two methods within these patients. Dotted lines indicate 95% confidence intervals.

Results: Fig. 1 shows the inline T2*-maps obtained in two volunteers along with the septal ROIs used to compute average myocardial T2* value. Fig. 2 depicts septal ROIs drawn on the DB-prep GRE images within CMRTools (A-1,B-1,C-1) and on the inline T2*-maps (A-2,B-2,C-2). In these 3 representative patients, the T2* estimates match closely as indicated by the values listed below each image. Fig. 3 illustrates statistical comparison between the T2* estimates computed using CMRTools and the ones obtained using inline analysis in all 32 patients.

Conclusions: The proposed technique computes pixel-wise T2* estimate, which is different from the region-based T2* assessment within CMRTools; however, the average T2* values within septum are highly correlated (R^2=0.996) with the region-based estimates obtained using CMRTools. This is an encouraging result given that T2*-maps are generated on the scanner without any need for user intervention to eliminate outliers, and that assessment of myocardial T2* is possible immediately following data acquisition. Prospective clinical studies are warranted to thoroughly validate this proposed method.

References:

[1] Pennell DJ, Ann. N.Y. Acad. Sci. 1054:373–378, 2005. [2] He *et al*, MRM 60:1082–1089, 2008. [3] He *et al*, JMRI 25:1205–1209, 2007.