Myocardial T1, T2 and T2* Measurements for in vivo Assessment of Iron Overload in Thalassemia

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Introduction: Cardiac complications secondary to iron overload are the leading cause of death in thalassemia major (TM). Cardiovascular magnetic resonance (CMR) can provide a noninvasive means of measuring the amount of tissue iron. With CMR, tissue iron is detected indirectly by its effect on relaxation times of hydrogen nuclei in the presence of ferritin and hemosiderin iron. The iron results in shortening of proton relaxation times and both CMR T2* and T2 have been validated as non-invasive means for assessment of myocardial iron overload. (1,2,3,4). We have demonstrated a linear correlation between T2 and T2* in patients with iron overload (5). However, there is currently little data on myocardial iron assessment using the longitudinal relaxation time T1 mainly due to the cardiac and respiratory problems in CMR.

A modified Look-Locker Inversion recovery (MOLLI) has been recently proposed for myocardial T1 quantification (6). It is of interest, therefore, to investigate whether T1 measurement is affected by iron overload in TM patients. For quantitative analysis, it is important to further investigate the relationship between T1 and the more established T2* and T2 measurements in TM patient population, which can help understand the underlying mechanism of CMR relaxometry and hence promote the myocardial tissue characterization in diagnosis and management of patients with different cardiac diseases. In this study, we are focusing on a direct comparison of in vivo myocardial T1, T2, and T2* measurements in order to establish their intrinsic relationships. We hypothesise that T1 correlates with T2* linearly when iron becomes dominant in the myocardium. We also hypothesise that T1 correlates linearly with T2 in subjects with or without iron overload.

Material and Methods:

48 TM patients (age 32±20 years old, 26 males) were studied on a 1.5T MRI scanner (Siemens Sonata) using a cardiac phased array coil and with ECG gating. All patients were scanned using the black blood T2* (3), the T2 (4), and the T1 (6) sequences subsequently, each within a breath-hold. A single mid-ventricular short axis slice was imaged with T1, T2, and T2* measured in the left ventricular septum (Figure. 1). The mono-exponential decay model and the nonlinear curve fitting algorithm were employed for T2 and T2* measurement (7,8) (CMRtools). T1 measurement was first acquired using MRMAP (http://www.cmr-berlin.org/forschung/mrmapengl/index.html) and the septal analysis was done by use of self-developed software in Matlab.

Results:

Figure 1 shows the relationship between T2 and T2* from all patients, while Figure 2 the relationship between T1 and T2*. The vertical broken line represents the previously established cut-off myocardial T2* value to distinguish abnormal (black dots) and normal (green dots) patients. The trend line in both figures is drawn from the data with T2* less than 20ms. It can be seen that there is a linear correlation between T2 and T2* (R^2 = 0.733), and between T1 and T2* (R^2 = 0.697) for patients with myocardial iron overload (T2* <20ms). In patients with no myocardial iron, however, no significant relation is present either for T2/T2* or T1/T2*. Figure 3 shows the relationship between T1 and T2 from all patients. The trend line (Figure 3) is drawn from all patient data (black dots). There is clearly a good linear correlation (R^2 = 0.856) between myocardial T1 and T2 measurements in the septum in all the patients with or without iron overload.

Conclusions:

Both myocardial T1 and T2 measurements correlated linearly with T2* measurements in TM patients with iron overload, suggesting that the iron deposition becomes the dominant factor determining CMR relaxometry in this scenario and that all three relaxation values (T2*/T2/T1) can be used for assessing iron overload in the heart. In patients with normal iron (T2* > 20ms), other factors become relevant which is confirmed by more scattered T2* data (Figures 1&2). Myocardial T1 correlates linearly with T2 measurements in all patients suggesting that these two relaxation values can avoid extrinsic magnetic field inhomogeneity effects and can potentially provide improved myocardial tissue characterization for patients with other non-iron loading cardiac diseases.

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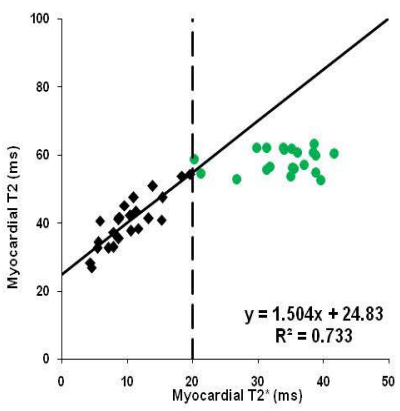

Figure 1. Correlation between T2 and T2*

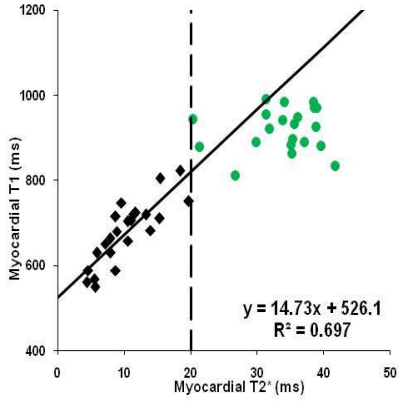

Figure 2. Correlation between T1 and T2*

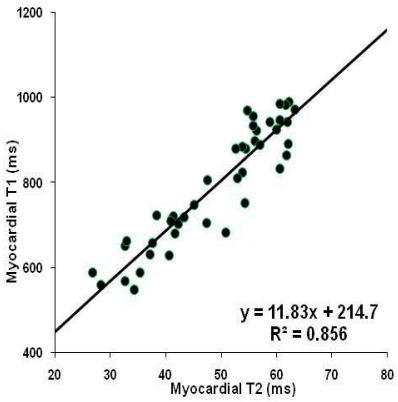

Figure 3. Correlation between T1 and T2