A dynamic Black-blood Scheme for Myocardial T2 Estimation in Thalassemia

Taigang He, Peter D Gatehouse, Mark Tanner, Gill Smith, Tim Cannell, Dudley J Pennell, David N Firmin
NHLI, Imperial College London & Royal Brompton Hospital, London, UK

• Introduction

Recent studies have shown cardiovascular magnetic resonance (CMR) can provide a non-invasive procedure for assessing the iron content of the myocardium, which is useful for early diagnosis and treatment (1, 2, 3). Previously, a T2* technique has been developed and clinically validated for this (1, 2). Conventional T2 measurement techniques have also been attempted but have not found widespread use because of lack of sensitivity, motion artifacts and poor signal-to-noise ratios (SNR) (1). The aim of this study was accordingly a) to develop and improve T2 measurement method for better quantification of myocardial iron concentration, and b) to compare the results with a clinically validated T2* technique. For this purpose, a breath-hold multiecho FSE sequence (BH-FSE) was developed. It permits acquisition of multiecho images in one breath-hold, but with relatively low resolution random noise. This sequence used a new flexible black-blood scheme to cancel blood signal, which was acquired every three heartbeats throughout the scan to achieve high inversion recovery time calculation in order to suppress the artifacts due to heart beat variations. Additionally, a non-selective refocusing train was adopted to suppress motion artefacts and to minimize stimulated echoes.

• Methods

The T2 measuremens were validated using a phantom made of 6 tubes filled with dilutions of gadolinium to cover the possible T2 range of myocardial tissue (10–1500 ms). A 1.5T scanner (Siemens Sonata) with 4-channel body array coil and gradient performance up to 40 mT/m and 2000 mT/m was used. Scans were synchronized to the cardiac cycle using standard ECG gating, and images were acquired during late diastole to avoid ventricular motion at a single slice oriented to give a short axis view of the left ventricle (LV). The sequence parameters were: the following: 10 mm slice thickness, Field of view (FOV) was 40 cm with in-plane rotation applied to reduce the phase encoding FOV in order to keep the scan time to an acceptable duration. The parameters for BH-FSE sequence were: turbo factor 3, 12 effective TE images (in 4 steps), 128x128 matrix, 10 Thalassemia patients undergoing MR scanning were used and chest saturation band was used for human subject imaging.

• Non-selective refocussing train was adopted to suppress motion artefacts and to minimize stimulated echoes, and large balanced gradients were used before and after all refocussing pulses in both slice selection and phase encoding directions to suppress image artefacts. Blood suppression was accomplished with a non-selective 180° inversion pulse followed immediately by an adiabatic slice-selective 180° inversion pulse (3). The inversion recovery time TI was determined close to the null point of blood signal:

\[
T1 = -TTR\ln\left(1 + \exp(-TR/T1)\right) 
\]

The TI of blood was taken to be 1200 ms and TR was dynamically updated to be the summation of the RR intervals from the previous two cardiac cycles (triggered during the real time scan) to avoid effect of RR interval variation. Images using conventional black-blood technique (2, TR, fixed) were also acquired for comparison. For phantom experiments, the TR was fixed at 2000 ms to be long enough to avoid T1 effect.

• Discussion

This work demonstrates that the blood signal is well suppressed with the proposed black-blood scheme (Fig. 1). It also shows that the developed T2 technique is robust to motion artifacts and has high SNR, which makes it possible to obtain accurate T2 measurements for better characterization of the myocardium. The method has also been implemented with navigation respiratory control allowing high resolution imaging.

We believe this is the first work to demonstrate that myocardial T2 values correlate linearly with T2* values from patients (Fig. 2). This may be of clinical importance, because T2 is unaffected by problems such as local susceptibility artifacts and may be helpful to characterise different forms of storage iron in conjunction with T2* values. Parameter optimization is necessary for further study and a more detailed analysis is needed to compare T2 and T2* values for early diagnosis and treatment of thalassaemia major.

• Acknowledgement

This work is part of the project “MR OF HEART IRON: T2*/T2 ESTIMATION IN THALASSEMIA” supported by NIH Grant: R01 DK66084-01.

• References


Table 1 T2 values (ms) of SE and BH-FSE from phantoms

<table>
<thead>
<tr>
<th>No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE</td>
<td>22.7</td>
<td>34.4</td>
<td>39.2</td>
<td>58.8</td>
<td>76.3</td>
<td>91.7</td>
</tr>
<tr>
<td>BH-FSE</td>
<td>24.3</td>
<td>36.5</td>
<td>42.0</td>
<td>63.3</td>
<td>81.3</td>
<td>97.1</td>
</tr>
</tbody>
</table>

Fig. 1 Comparison of Blood Suppression Effect

Fig. 2 T2 vs T2*