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

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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, 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 images. This sequence used a new flexible black-blood scheme to cancel blood signal, where real time RR intervals are acquired during scan for real-time 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 tissues (20-100ms). A 1.5T scanner (Siemens Sonata) with 4-channel body array coil and gradient performance up to 40mT/m and 200T/m/s 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 40cm with in-plane rotation applied to reduce the phase encoding FOV in order to keep the scan time to an acceptable duration. Other parameters for BH-FSE sequence were: turbo factor 3, 12 effective TE images (TE=4.8–163.2ms in 14.4ms steps), 128*64 matrix. 10 Thalassemia patients undergoing MR scanning were studied and chest saturation band was used for human subject imaging.

Non-selective refocusing train was adopted to suppress motion artifacts and to minimize stimulated echoes, and large balanced gradients were used before and after all refocusing pulses in both slice selection and phase encoding directions to suppress image artefacts. Blood suppression was accomplished with a nonselective 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:

$$TI = -T1 \bullet \ln\left[\frac{1+\exp(-TR/T1)}{2}\right] \quad (1)$$

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

The effectiveness of blood suppression was evaluated according to the myocardium/blood signal ratio from each patient. The signal intensities (mean of ROI) were measured from myocardium and blood pool of the short axis images. In total 60 pairs of images were chosen randomly from the patients. The results were compared and analyzed using a paired t-test (MATLAB). The measured myocardial signal intensities (mean of ROI) for different echo times was fitted by using a nonlinear regression to determine both T2 and T2* (CMRTOOLS, Imperial College). The methods were tested and compared with measured T2* in 10 thalassemia patients.

Results

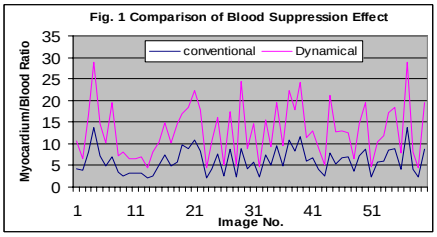
For the phantom study, multiple standard SE measurements were taken as the gold standard. The values of T2 obtained with the phantom (Table 1) show minor differences between BH-FSE and SE sequences.

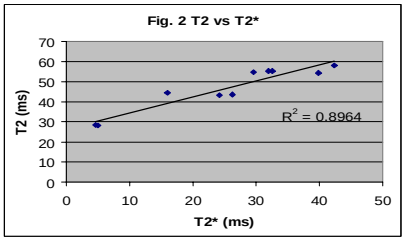
BH-FSE images in the short axis planes from human subjects demonstrated good blood suppression and high contrast. The comparison of myocardium/blood ratio between conventional black-blood technique and the proposed dynamical scheme was plotted in Figure 1. The new scheme (purple line) was shown to be much better and a paired t-test indicated a significant difference between the two series (p=0.0005).

The measured T2* and T2 values for each patient were plotted in Figure 2 with a linear regression trend line added.

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

No.	1	2	3	4	5	6
SE	22.7	34.4	39.2	58.8	76.3	91.7
BH-FSE	24.3	36.5	42.0	63.3	81.3	97.1





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 higher resolution imaging.

We believe this is the first work to demonstrates that myocardial T2 values correlate linearly with T2* values from patients (Fig.2). This may be of clinical importance, because unlike T2*, T2 is unaffected by problems such as local susceptibility artifacts. 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

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References

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