

A Black Blood T2* Technique for Myocardial Iron Measurement in Thalassemia

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Introduction

Recently, iron detection using T2* values derived from Cardiovascular magnetic resonance (CMR) has been validated and shown potential to monitor chelation regimens (1, 2, 3). Sufficient contrast between the myocardium and the blood pool is required to accurately define the borders along with minimal image artifacts for accurate T2* estimation. This T2* technique has been optimised to minimise image artifacts. However, it does not provide particularly high contrast between the signal from blood in the left ventricle and the signal from the myocardium. Additionally, a proportion of images that are acquired appear to have blood signal artifacts and partial volume effects that would most likely reduce the accuracy of the T2* measurement.

In this work a comparison was made between the black blood sequence and the conventional bright blood one. Firstly, measurements of T2* were compared to see if the apparent blood artifacts affected the measurement. Inter-observer variability was also measured as this is an important factor for monitoring of response to treatment.

Methods

The study was approved by the local ethics committee. 15 human subjects (5 normal volunteers and 10 thalassemia patients) were studied on a 1.5T whole-body Siemens Sonata system equipped with fast gradients having a maximum strength of 40mT/m and maximum slew rate of 200T/m/s on each axis independently. A four-element cardiac phased array coil was used to increase SNR.

Scans were synchronized to the cardiac cycle using standard ECG gating. A single 10 mm thick short axis mid-ventricular slice positioned half-way between the base and the apex of the left ventricle (LV) was acquired at eight echo times (2.6–16.74 ms which increased in 2.02 ms increments) with standard shimming in a single breath-hold. For both bright and black blood imaging, a gradient-echo sequence was used with a flip angle of 20°, a matrix of 128 x 256 pixels, a field of view of 40 cm, and a sampling bandwidth of 810 Hz per pixel. This gives a voxel size of 3.1 · 1.6 · 10 mm. For black blood imaging, the double inversion pulses were applied at the R wave trigger to minimize the effect of fast pulsation blood flow within the LV. Inversion time was set to extend over systole allowing the re-inverted blood within the slice plane to be replaced by initially inverted blood and also allowing the myocardium to move back to the same plane after systole.

A homogeneous full thickness region of interest (ROI) was chosen in the left ventricular septum, encompassing both epicardial and endocardial regions. The signal intensity (mean ROI) was measured for each of the images, and the data was plotted against the echo time to form an exponential decay curve. The Levenberg-Marquardt method of nonlinear estimation (CMRTOOLS, Imperial College) was employed to produce more accurate estimate of T2*.

T2* analysis was performed by two independent observers. Bland–Altman analysis (4) of the data was performed to determine whether there was a bias between the readers. The coefficient of variation was defined as the standard deviation of the differences between the two separate measurements, divided by their mean, and expressed as a percentage. A scatter plot with the line of identity was drawn for comparison.

Results

Images in the short axis planes from human subjects demonstrated good blood suppression and high contrast from black blood images. Representative images acquired from the same mid-ventricular slice for both the bright and the black blood sequences are shown in Fig.1. The black blood myocardial septum appeared distortion-free (Fig.1, left), while the bright blood image (Fig. 1, right) showed more obvious artifacts inside myocardium and obscured borders. As a result, the estimated T2* value (average of two independent observers) for this particular subject was 21.3ms for bright blood images, 23.2% greater than that (16.9ms) from black blood images.

For all the subjects studied, the mean T2* value obtained from bright blood images was 40.5±16.8ms, and 31.9±12.5ms from the black blood ones. The coefficient of variation for bright and black blood image comparison was 16.1%. The coefficient of variation for inter-observer variability was found to be 9.1% for bright blood image analysis, and 2.4% for black blood image analysis. Fig. 2 showed the scatter plots to compare the paired series; obvious skewing can be seen between the T2* values obtained from bright and black blood image (Fig. 2: left). Reduced inter-observer variability for black blood technique was shown (Fig. 2: middle and right).

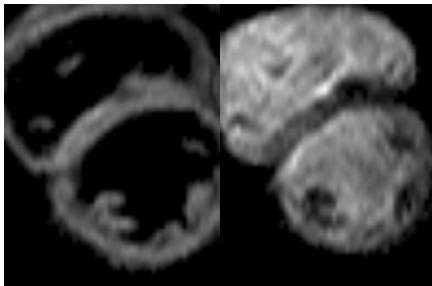


Figure 1. Representative images of black (left) and bright blood images (right) from the same subject at TE of 8.66ms

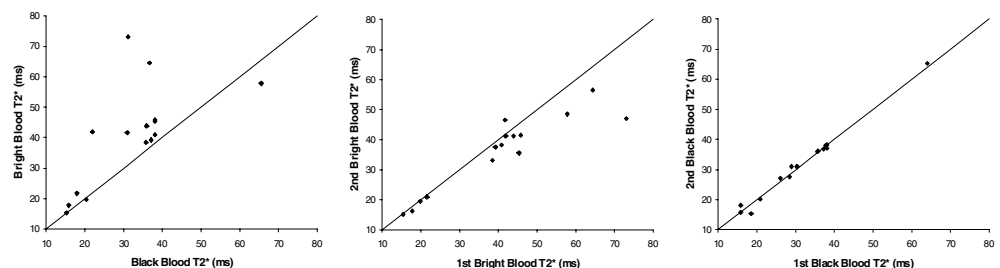


Figure 2. Scatter plots of the myocardial T2* values with the line of identity, showing comparison between bright and black blood images (left), also between two observers for bright (middle) and black (right) blood image analysis.

Discussion and Conclusion

We have demonstrated that the black blood T2* technique for measuring iron concentrations in the heart compares favourably over the conventional bright blood sequence. Previous work has shown inter-study consistency of the bright blood sequence, but in this study we further improved this method by using a black blood technique which produced high quality images and better inter-observer variability. In Addition, the two techniques have been shown to be consistent when measuring a representative range of T2*'s in a non-moving phantom.

In conclusion, the black blood T2* sequence has shown reduced variability between readers and proved to be effective by yielding high contrast images, providing superior myocardial border definition, largely reducing blood signal contamination from the myocardium. The technique can thus provide a more reliable measurement of the T2* for quantifying myocardial iron deposition, which allows for better characterization of the myocardium and facilitates its clinical application. This technique may have potential to study other disease requiring T2* analysis.

Acknowledgement

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References

1. Anderson LJ, Holden S, Davies B, et al. Eur Heart J 2001;22:2171–2179.
2. Westwood M, Anderson LJ, Firmin DN, et al. J Magn Reson Imaging. 2003 Jul;18(1):33-9.
3. Anderson LJ, Wonke B, Prescott E, Holden S, et al. Lancet 2002;360:516–520.
4. Bland JM, Altman DG. Lancet 1986;1:307–310