Free-breathing Technique for Myocardial T2* Measurement with GRE multi-echoes Pulse Sequence

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Introduction

Heart failure, secondary to myocardial siderosis, remains a major problem for patients with transfusional iron overload [1]. T2* myocardial Magnetic Resonance Imaging (MRI) is a non-invasive technique which is able to assess tissue iron levels [2]. However, accuracy and reproducibility of the T2* measurement depend on the quality of MR images as well as selected curve fitting models [2-5]. Currently, single breath hold black blood technique has been used in most centers [6 7]. The major limitation of the breath-hold technique is that acquisition time is constrained by the capability of breath holding in each individual resulting in limited SNR and resolution on images. We proposed a new technique to overcome the limitations with a Free breathing GRE black blood multi-echoes providing higher SNR and resolution images ensuing the improvement of effectiveness and reproducibility of T2* measurements.

Purpose

The objective of this study was to compare the effectiveness and reproducibility of breath-hold versus free-breathing GRE black blood multi-echoes techniques for myocardial T2* measurement.

Materials and methods

All techniques used in this study were validated in a phantom study prior to performing in normal volunteers. Informed consent for MRI and a review of the medical data were approved by an institutional review board. The MRI scanner used in this study was a 1.5 Tesla, (Achieva, Philips, Netherland). The phantom data were acquired from an in-house building phantom incorporated 8 different concentrations of Ferricchloride ($FeCl_3.6H_2O$) which corresponds to the T2* ranging from 3 to 40 msec. The in vivo data were collected from 15 healthy volunteers (7 males and 8 females, ages between 20-34 years old). A single short-axis view of the mid left ventricle was acquired at ten echo times (1.70 – 26.10 msec. an increment of 2.70 msec.). A double inversion recovery was used to acquire black blood image. For the single breath-hold technique, T1-FFE sequence was used with flip angle of 25º, matrix 164 x 154, FOV 36 cm, TR 28 msec, and 1 NSA. For the free-breathing technique, pulse sequence and most parameters were kept the same except matrix and NSA that were optimized with the compromise of total acquisition time and image quality. A navigator pre-pulse was used to reduce motion artifact. The truncation and offset models with Levenberg-Marquardt curve fitting algorithm were used to evaluate T2* values. The data analysis was performed on a PC using MATLAB7.01 (Mathworks, Natick, MA, USA), and SPSS for window V.17.

Results

The correlation between phantom iron concentration (mg Fe^{3+}/g wet weight) and R2*(1/T2*) using Pearson's test showed strongly correlation with a correlation coefficient of 0.996 (P<0.001) as in Fig1. Mean SNRs of the free-breathing technique from the first TE (1.7 ms) to the last TE (26.1 ms) were higher than those of the breath-hold technique by approximately 44.12% to 45.19 % as in Fig.2. Free-breathing technique allows greater numbers of signal average (NSA) and increase of resolution from 2.3x3.2 mm per pixel to 1.61x1.67 mm per pixel as an example in Fig.3a and 3c compared to those of the breath-hold as in Fig. 3b and 3d at the same TEs. Bland-Altman plots demonstrated that the T2* values of free-breathing technique had less variation or better reproducibility between two studies in both fitting models compared to those of the breath-hold technique as in Fig.4. Wilcoxon signed-rank test also showed that the mean T2* obtaining from free-breathing technique was no significant different between the two different fitting models, truncation and offset models, with the T2* of 36.50± 2.41 ms., and 35.18± 4.20 ms respectively (CI=95%, p=0.080), while the mean T2* obtaining from the breath-hold technique showed significant different between the two different fitting models, with the T2* of 36.45± 2.90ms and 30.41± 7.86 ms (CI=95%, p=0.0002).

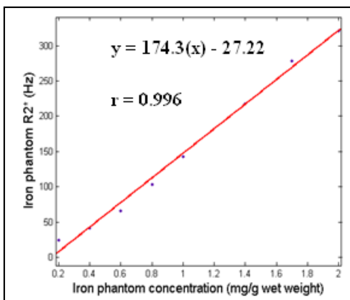

Figure1. Phantom with 8 iron concentrations (mg Fe/g wet weight) showed linearly correlation to the R^2* with a correlation coefficient of 0.996

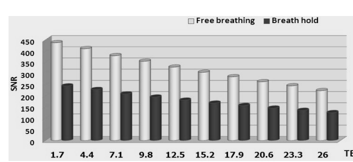

Figure2. Graph of SNR, the free-breathing provided higher SNR than that of the breath-hold in first TE through the late TE.by approximately 44.12% to 45.19 %

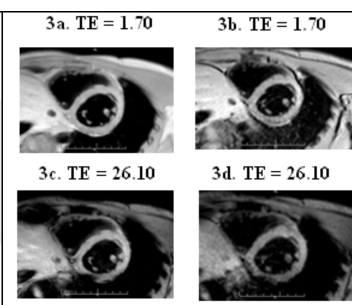

Figure3. shows higher resolution images of the free-breathing technique (3a and 3c) and lower resolution images of breath-hold (3c and 3d) at TE=1.7 ms. and 26.1 ms.

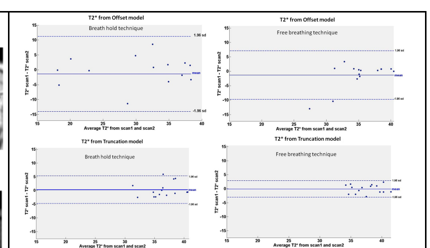

Figure4. Bland-Altman plots showed less variation reflecting better inter-study reproducibility of the myocardial T2* values obtaining from free-breathing images, compared to those of the breath-hold

Discussion and Conclusion

Breath-hold technique showed significant different T2* between the 2 fitting models 36.45 ± 2.90 msec., and 30.41 ± 7.86 msec., (p = 0.0002) due to the contribution of higher noise level. For the free-breathing technique which noise was reduced by increasing numbers of NSA up to six, the T2* was found more independent to the fitting models (T2* =36.50± 2.41 ms., and 35.18± 4.20 ms, no significant different with p = 0.080). Though, the free-breathing technique is required longer total acquisition time up to 108 s for 6 NSA, it is still practical to do. In conclusion, the free-breathing T2* technique is promisingly an alternative technique for T2* mapping because it provided greater reproducibility of T2* and should be more appropriate for patients who have difficulty in holding breath during scan.

References

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