Comparison of Navigator-Gated and Breath-Held Measurements of R2, R2*, and R2' for the Assessment of Hepatic and Myocardial Iron Content

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Introduction

Over the past several years, there has been an increased interest in using MRI for iron assessment for iron overloading diseases by measuring the transverse relaxation rates R_2, R_2*, and R_2' (1-3). Recently, the GESFIDE (gradient-echo sampling of free induction decay and echo) pulse sequence (4) has been shown to be an efficient means to measure the transverse relaxation rates R_2*, R_2 and R_2' in murine liver specimen (5, 6). In this study, thalassemia patients are examined using navigator-gated GESFIDE pulse sequences, allowing free-breathing determination of the relaxation parameters in a single scan. Comparisons with conventional breath-held methods are performed in these patients as well as in normal volunteers, and the correlations among R_2*, R_2, and R_2´ investigated.

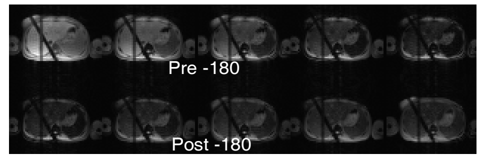

Fig. 1. Navigator-gated GESFIDE liver images of a thalassemia patient. The two dark bands are due to the slice-selective excitation and refocusing navigator pulses.

Methods

In GESFIDE, a train of gradient echoes is acquired following the excitation pulse and a second set of echoes following a 180^o refocusing pulse. When fit to a decaying exponential, the echoes prior to the 180^o yield R_2* (= R_2 + R_2'), while those following evolve with a rate constant R_2^- (= R_2 - R_2'). R_2 and R_2' could subsequently be computed by a linear combination. Two variations of a navigator-gated GESFIDE pulse sequence were developed to measure transverse relaxation rates in the liver and the heart. For the liver, a navigator through the liver/diaphragm was used to monitor respiratory motion, and parallel inferior-superior spatial saturation and fat saturation pulses used to suppress flow and fat signals, respectively. For the heart, in addition to navigator and ECG-gating, double inversion (DIR) preparatory pulses were used for the suppression of the blood signal (7). To validate these free-breathing GESFIDE techniques for the measurement of R_2*, R_2 and R_2' in patients, a breath-held GESFIDE (without navigator gating) and a multi-echo gradient echo (MGRE) were also performed on the liver and heart, respectively, for comparison.

Twelve thalassemia patients and 3 healthy volunteers (6 male, 9 female, mean age = 33.4 ± 9.8) were scanned on a 1.5T Siemens Sonata scanner. Scan parameters for the liver were as follows: 64x56 matrix size; FOV=35 x 30 cm^2; thickness=10 mm. Four or five echoes were acquired for each echo train, and echo spacing varied between 0.8 and 5ms depending on the subject. The TR was 600ms or 200ms for navigator-gated and breath-held methods, respectively. For the heart: slice thickness = 10 mm; TR = 1RR; 192x128 matrix size; FOV = 370 x 250 cm^2; 5 echoes per echo train, echo spacing between 3 and 5 ms. In addition, a breath-held, segmented multi-gradient echo sequence was acquired for comparison purposes: 5 echoes with echo spacing of 3 to 5 ms, and 9 segments per heart beat. Regions of interest (ROI) were manually outlined for the heart (interventricular septum) and the liver, and the transverse relaxation rates, R_2* and R_2^- were obtained from linear least-square regression fits of the log of the signal amplitudes of the two echo trains, and R_2 and R_2' from their linear combinations.

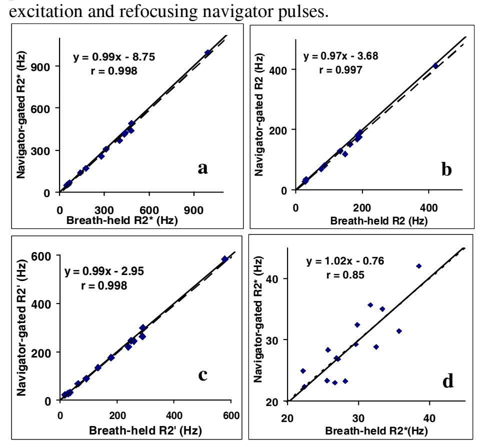

Fig. 2. Comparison between navigator-gated and breath-held methods for R_2*(a), R_2(b), R_2'(c) of the liver, and R_2* of the heart (d). Both the fitted (dashed) and equality (solid) lines are shown.

Results and Discussions

The overall image quality of navigator-gated images was similar to that of the breath-held scans. For the liver (**Fig. 1**), there were excellent agreements between the navigator-gated and breath-held scans (r = 0.997-0.998, and P < 0.0001) (**Fig. 2a-2c**). The fitted slopes (dashed lines) ± 95% confidence limits were 0.99 ± 0.033, 0.97 ± 0.050 and 0.99 ± 0.041, and those for the intercepts were -8.75 ± 13.5, -3.68 ± 8.9 and -2.95 ± 10.1 s^{-1} for R_2*, R_2 and R_2', respectively. For the heart (**Fig. 3**), good agreement in R_2* values obtained with GESFIDE and MGRE were also found with r = 0.85 (P < 0.0001) (**Fig. 2d**). The fitted slope ± 95% confidence limit was 1.02 ± 0.38 and for the intercept -0.77 ± 11.33 s^{-1}.

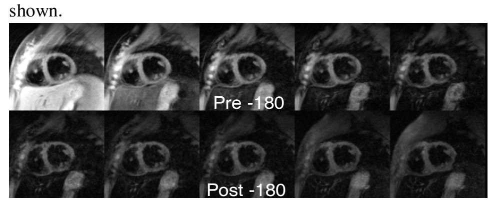

Fig. 3. Series of images obtained with a dark-blood, navigator-gated GESFIDE sequence in a thalassemia patient.

The correlation between R_2* and R_2 and between R_2' and R_2 are shown in **Fig. 4**. The high degree of correlation in the liver indicates that the three parameters may be equally predictive in determining iron content. Since R_2 and R_2' may be preferentially sensitive to ferritin and hemosiderin, respectively (8), a good correlation between the two (r = 0.994 and P < 0.0001 for the liver) may suggest that the relative fractions of these two compounds in the livers observed in this study were approximately constant. In the heart, correlations were somewhat weaker, most likely due to a much smaller range of relaxation rates as well as possible residual cardiac motion. The data in **Fig. 4** were obtained from the navigator-gated techniques, but similar correlations were also observed in breath-held scans.

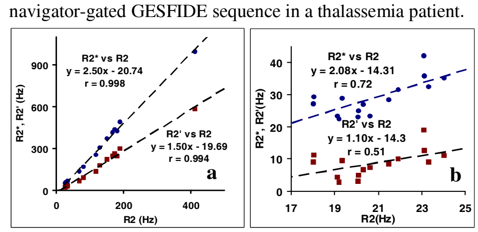

Fig. 4 The correlations between R_2* and R_2 (circles) and between R_2' and R_2 (squares) for the liver (a) and the heart (b). The above data were from the navigator gated data set.

Conclusion

Thalassemia patients and healthy volunteers were studied using free-breathing, navigator-gated, dark blood GESFIDE pulse sequences. Solid agreements in R_2, R_2*, and R_2' between navigator-gated and breath-held scans were found, demonstrating that navigator-gated techniques may be used in place of breath-held methods. Free-breathing, navigator-gated methods may improve patient tolerance and prove beneficial when imaging children or sick subjects. The good correlations among R_2, R_2*, and R_2' indicate that the measurement of any of these parameters may be effective in assessing tissue iron levels, corroborating earlier findings in the liver (1).

Acknowledgement: R01-DK-066129

References: (1) Wood JC, et al, Blood, 106:1460-5(2005); (2) Westwood M, et al. J Magn Reson Imaging 18:33-9 (2003) ; (3) Clark PR, St Pierre TG. Magn Reson Imaging 18:431-8 (2000); (4).Ma J, *et al*, J. Magn. Reson. B111:61-9 (1996); (5) Song HK *et al*, Proc. ISMRM, Miami, p. 1885 (2005); (6) Song R *et al,* Proc. ISMRM, Seattle, p 3305 (2006); (7) Song R, Song HK, Proc. ISMRM, Seattle, p. 2521(2006) ; (8) Haque TL, et al. Eur J Radiol 48(3):230-6(2003).