Free-breathing, dark-blood GESFIDE pulse sequence for the measurement of R2*, R2 and R2' of myocardium

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Introduction

An accurate measurement of transverse relaxation parameters R_2, R_2*, and R_2' in the liver and the heart is of growing importance in non-invasive determination of iron concentration in subjects with iron-overloading diseases such as thalassemia. Multiple breath-held scans are typically required to obtain these parameters, but it would be desirable to obtain the rates without the need for breath-holds due to the possibility for image misregistration and reduced patient tolerance. The GESFIDE (gradient-echo sampling of free induction decay and echo) pulse sequence has been shown to be an efficient means to measure these relaxation rates in a single scan (1-2). However, due to the need for cardiac gating, the scan cannot be performed in a single breath-hold for imaging the heart, one of the target organs of the disease. In this study, methods to allow free-breathing GESFIDE scans are explored for the accurate measurement of transverse relaxation parameters in the myocardium.

Methods and Results

Double Inversion Recovery (DIR) *preparation*: Signal from blood (either in the chambers or the vessels of the heart) could affect transverse relaxation rates either by direct contribution to the measured signal or by ghosting artifacts. To suppress signal from blood, a dual-inversion preparation, consisting of a non-selective 180° followed by a slice-selective 180° restoration pulse (3), was applied following the R-wave (**Fig. 1**). A TR-dependent inversion time TI is selected to effectively null the blood signal when the image data is acquired. Since the non-selective 180 undesirably inverts the diaphragm/liver signal needed for respiratory gating, resulting in reduced navigator signal, an additional slice-selective 180° pulse (Nav-Restore) affecting a slice that coincides with that of the 90° navigator excitation was employed to restore the magnetization back to the +z axis (4). Navigator signal enhancement of a factor greater than 3 was achieved in this manner.

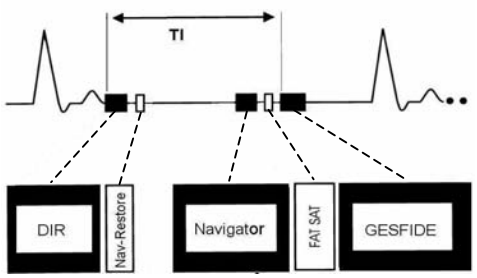

Fig. 1. Free-breathing, dark blood GESFIDE sequence.

Respiratory gating: To suppress bulk cardiac motion due to respiration and allow free-breathing acquisition, prospective navigator gating was implemented (5). Prior to the acquisition of the image data, a 90°-180° crossed-pair navigator beam with a short echo time (4 ms) was employed to ensure sufficient navigator signal in subjects with short liver T_2 which could be on the order of a few milliseconds. The navigator beam was positioned at the dome of the right hemidiaphragm, and the end-expiratory position was chosen with an acceptance window of ±4 mm. Acceptance rates of approximately 50% were obtained.

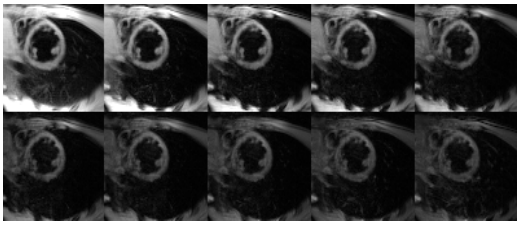

Fig. 2. Cardiac images using the proposed sequence. Five echoes pre- (top row) and post-180° (bottom) are shown.

GESFIDE: In GESFIDE, a train of gradient echoes is acquired following the excitation pulse and a second set of echoes following the 180° refocusing pulse (1). When fit to a decaying exponential, the echoes prior to the 180° 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. The desired parameters R_2*, R_2, and R_2' therefore could be acquired efficiently in a single scan.

The above sequence was implemented on a 1.5T Sonata Siemens scanner. Oblique, short-axis images of the heart of three normal volunteers were scanned using the spine and torso phased array coils with the following parameters: TR = 1xRR or 2xRR; FOV = 30x30 cm^2; 128x128 matrix size; 10 mm slice thickness; 5/5 echoes pre/post-180°; 4ms inter-echo spacing; receiver bandwidth = ±64kHz. Fat saturation was applied to reduce signal from the chest wall.

Fig. 2 shows representative free-breathing, dark blood images of the heart in one of the volunteers. Respiratory motion artifacts are effectively eliminated, and the blood signal well-suppressed. **Fig. 3** shows the GESFIDE signal evolution and the measured relaxation values in a region encompassing the myocardium.

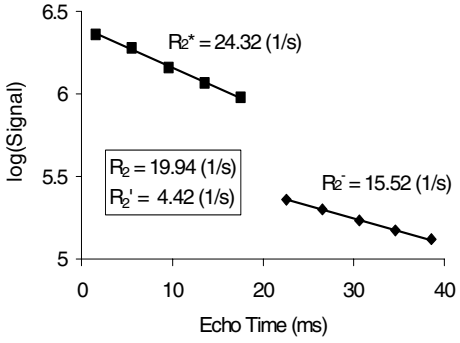

Fig. 3. The GESFIDE signal evolution. R_2* and R_2^- were determined by linear regression, and R_2 and R_2' by subsequent linear combination.

Conclusion

A free-breathing, dark blood GESFIDE pulse sequence was developed for the measurement of the transverse relaxation parameters R_2, R_2*, and R_2' in the heart. Enhancements to the sequence included a short TE crossed-pair navigator and a nav-restore inversion pulse to maintain strong respiratory gating signal. The improved sequence enables the measurement of transverse relaxation rates of the myocardium in a single free-breathing scan. The sequence precludes the need for multiple breath-held scans and possible misregistration problems, and may improve patient tolerance.

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References:

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