A T2-weighted SSFP-TSE hybrid: Gradient Moment Nulling and 180o Refocusing Pulses for Bright Blood Myocardial Edema Imaging

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Introduction

Imaging myocardial edema can differentiate acute from chronic myocardial infarction (MI) and determine the ischemic area at risk (1, 2). The double inversion recovery (DIR) preparation and TSE readout (3) result in suboptimal blood suppression due to reduced motion of blood. Moreover, imperfect positioning of the readout during diastasis can result in signal losses due to through-plane cardiac motion with respect to the DIR preparation.

An SSFP-TSE hybrid is proposed for bright blood imaging of edema associated with acute MI. In-vivo and phantom experiments show that this method yields T2 contrast to differentiate normal from ischemic myocardium while simultaneously preserving bright blood contrast.

Methods

The SSFP-TSE hybrid can be considered a gradient moment nulled TSE pulse sequence. In other words, instead of deliberately dephasing moving spins by bracketing the 180^o refocusing pulses in TSE with gradient crushers, the SSFP-TSE hybrid rather employs gradient moment nulling along all three directions so that moving spins retain phase coherence. As a result, with the SSFP-TSE hybrid, moving blood will appear bright rather than dark as is the case with conventional TSE images.

SSFP-TSE and conventional DIR-TSE experiments were performed at 1.5T. A four channel phased head array was used for phantoms and an eight channel phased array for in-vivo experiments. Imaging parameters were as follows: FOV 280x166mm, slice thickness 6mm, matrix 192x144, echo spacing 3.6ms, ETL 25, TE=60ms, triggering every third heart beat (~3.2 sec). To accommodate gradient moment nulling within the same echo spacing, the bandwidth for SSFP-TSE was 960Hz/pixel whereas for TSE it was 789Hz/pixel. Since phase correction was used by the product TSE pulse sequence, the total acquisition time was 18 heartbeats instead of 15 heartbeats for SSFP-TSE. The same parameters were used for phantom and in-vivo experiments.

The T1 and T2 of the CuSO4 doped agar phantoms A, B and C were measured with inversion recovery and spin echo experiments at TR>5*T1 (T1/T2 were: A=158/51ms, B=813/53ms, C=882/65ms). Phantom B simulates normal myocardium and phantom C edematous myocardium.

Eight dogs underwent 90 minutes of left anterior descending coronary occlusion followed by reperfusion. All animals were imaged three days post MI. In-vivo images were qualitatively evaluated for the presence of imperfect blood suppression and posterior wall signal drop out.

Results

When comparing phantoms B and C (i.e. “normal” and “edematous” myocardium) with similar T1 values but different T2 values, SSFP-TSE yielded SNR values of 164.7±4.9 and 190.9±4.3 respectively. Conventional DIR-TSE yielded 142.8±4.6 and 175.5±4.6 respectively. Despite the more than fourfold shorter T1 value of phantom A when compared to B, the SSFP-TSE hybrid yielded for phantom A SNR of 156.3±5.5 The corresponding value with the conventional DIR-TSE was 134.9±3.4. These results suggest that SSFP-TSE is a T2-weighted imaging sequence with minimal T1-weighting.

SSFP-TSE and conventional dark blood TSE images of edema associated with an acute subendocardial MI (as evidenced by gadolinium delayed enhancement, Gd-DE) are shown in the figure. The edema associated with the MI is well differentiated from both the bright-blood contrast and the darker normal myocardium with SSFP-TSE. Suboptimal blood suppression in the TSE image near the subendocardium leaves bright pixels near the infarct and along most of the septum. In all 8 animals, conventional TSE exhibited similar suboptimal blood suppression. No such ambiguities existed with SSFP-TSE. In 3 out of 8 animals posterior wall drop out was seen with conventional TSE. SSFP banding artifacts were seen in one animal on SSFP-TSE images.

Discussion

SSFP-TSE is a method which combines characteristics of both SSFP and TSE to yield bright-blood quality T2-weighted images of edema in acute myocardial infarction. SSFP-TSE can be seen as a gradient moment nulled TSE pulse sequence or equivalently as an $\alpha/2$-TR/2 prepared SSFP pulse sequence with a flip angle of $\alpha=180^o$. Interestingly, the SSFP-TSE pulse sequence can also be explained as a special case of a recently proposed T2-TIDE single-shot pulse sequence (4), where the transient phase is extended for the entire acquisition. SSFP-TSE shows promise for imaging edema associated with acute MI.

References

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