

## Flow-insensitive magnetization preparation for T2\* contrast

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### Introduction

T2\* weighted MR imaging provides a very useful contrast for blood oxygen level dependent (BOLD) imaging [1], the assessment of iron overload [2], or the detection of superparamagnetic iron oxides in molecular MR imaging [3]. The desired T2\* contrast is usually obtained using gradient echo sequences with long echo times (TE). However, the accumulation of phase errors of moving spins in the gradient field during prolonged TE can introduce severe artifacts, particularly due to flow in BOLD imaging. To overcome this drawback, an alternative technique is proposed in the present study. The acquisition is subdivided into an imaging portion with short TE to minimize flow artifacts, and a separate contrast preparation portion. The desired T2\* contrast is achieved in a fashion similar to T2 preparation [4], but involves RF pulses with variable spectral bandwidths to address the different spectral properties of oxygenated and deoxygenated blood. All preparation pulses are nonselective, i.e., no gradients are applied. This eliminates the sensitivity to motion and flow. The novel contrast preparation sequence has been implemented on a clinical MR system and tested *in vivo* in healthy volunteers.

### Methods

The basic principle of the proposed contrast preparation pulse is shown in Fig. 1(a). It is based on the fact that species with a long T2\* decay constant, such as oxygenated blood, have a narrow MR frequency spectrum ( $\Delta F_1$ ), while species with short T2\* constants (deoxygenated blood) have a broader MR frequency spectrum ( $\Delta F_2$ ). A preparation pulse sequence for the suppression of short T2\* species is shown in Fig. 1(b). A long (15ms) nonselective 90° RF pulse with narrow bandwidth tips the magnetization of  $\Delta F_1$  species into the transversal plane. A short 180° refocusing pulse (2.5ms) with broad bandwidth refocuses these components and inverts  $\Delta F_2$  species. A final 90° RF pulse (2.5ms) tips the refocused magnetization of  $\Delta F_1$  species back into the longitudinal direction, while the inverted magnetization of  $\Delta F_2$  species is tipped into the transversal plane and crushed by gradient spoilers. The sequence parameters of the actual imaging portion used for the validation study were as follows: 2D GRE, resolution 2.34mm in-plane, 10mm slice thickness, TE/TR = 2.1ms/4.2ms, ECG-triggering, cardiac acquisition window  $T_{AQ} = 65$ ms, scan duration 8 heart beats (single breathhold). Three images in short-axis view of the heart depicting left and right ventricle (LV and RV) were acquired in total. Two images were acquired with the given imaging sequence, where one scan was performed without contrast preparation, and one with the present contrast preparation pulse performed prior to imaging in each cardiac cycle. For comparison, one additional image was acquired with a prolonged echo time (TE=15ms) for conventional T2\* contrast generation. In all experiments, local shimming was performed in a cubic volume around the heart to reduce large-scale susceptibilities. First *in vivo* experiments were performed in 3 healthy adults on a clinical 1.5T scanner (Achieva, Philips Medical Systems).

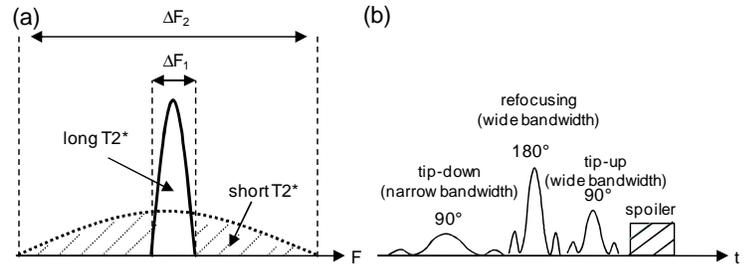


Fig. 1 Spectral properties of different T2\* species (a), T2\* preparation pulses (b)

### Results

Selected *in vivo* images (short axis view depicting RV and LV) are shown in Fig. 2 (a)-(c). Imaging without contrast preparation (a) yields no contrast between deoxygenated and oxygenated blood in the RV and LV, respectively. Using the T2\* preparation pulse, deoxygenated blood in the RV is suppressed, and a strong contrast between RV and LV is achieved (b). T2\* weighted imaging by means of prolonged TE yields non-diagnostic image quality due to flow artifacts along the phase encoding dimension (c).

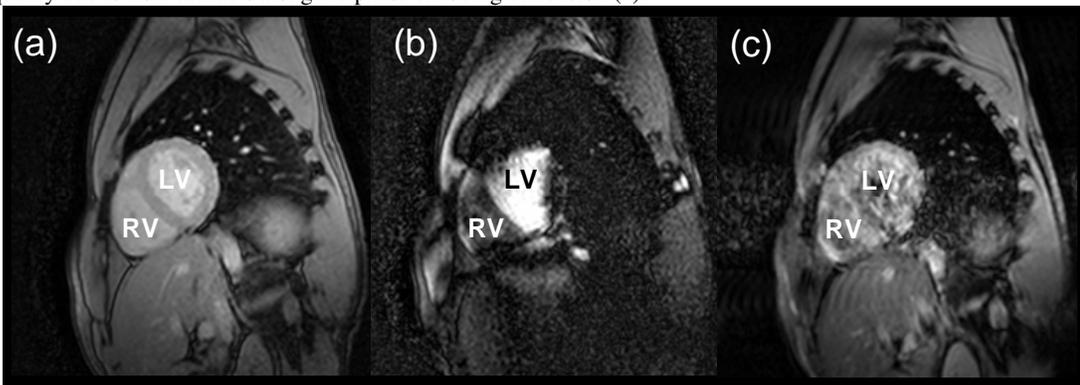


Fig. 2 Short axis views acquired with imaging sequence with short TE (a), additional T2\* contrast preparation (b), and conventional T2\* weighted imaging with long TE (c).

### Discussion and conclusion

The present flow-insensitive T2\* preparation pulse yields a strong suppression of short T2\* species, allowing for a clear differentiation of deoxygenated and oxygenated blood in the RV and LV, respectively. Additional signal suppression was observed outside the shim volume, such as in the liver and chest wall; however, this did not compromise the blood pool contrast. Flow artifacts were avoided due to the short TE in the actual imaging portion. The technique was applied in the heart, which represents a challenging anatomy for T2\* weighted MR imaging due to large-scale susceptibility differences at the lung-heart interface, flow, and motion. Nevertheless, all examinations were completed successfully, and the method appears to be a promising tool for flow-insensitive BOLD imaging. More experiments in a larger patient population and a variety of anatomies are needed for a further validation of the present technique.

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