Towards Non Contrast Agent Myocardial Perfusion Imaging Using Spin-Echo Based Images with Blood Oxygenation Level Dependent Contrast at 3.0 T

U. Heinrichs[1], T. Frauenrath[1], J. F. Utting[1,2], G. A. Krombach[3], R. W. Günther[3], and T. Niendorf[1]

[1]Department of Diagnostic Radiology, Division of Experimental Magnetic Resonance Imaging, University of Aachen, University Hospital, Aachen, Germany, [2]IZKF-BIOMAT, University of Aachen, University Hospital, Aachen, Germany, [3]Department of Diagnostic Radiology, University of Aachen, University Hospital, Aachen, Germany

Introduction

In current clinical MRI practice first passage kinetics of a bolus of contrast agent are used to detect myocardial perfusion deficits. Obstacles to a broader clinical acceptance of first-pass myocardial perfusion MRI are (i) limited in-plane spatial resolution (approximately (3 x 3) mm^2) and (ii) limited anatomic coverage, due to the competing constraints of the short first passage of contrast agent, temporal resolution, signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR). In addition patients with severe kidney impairment are at risk of nephrogenic systemic fibrosis (NSF) after gadodiamide administration (1, 2). Perfusion imaging based on BOLD (Blood Oxygen Level Dependent) contrast serves to avoid these constraints using T_2*-weighting, conventionally realized by echo planar imaging (EPI) or conventional gradient echo imaging techniques (3). Drawbacks here are the poor image quality and reproducibility due to EPI's intrinsic sensitivity to B_0-inhomogeneities and artifacts due to ventricular blood flow. To overcome these limitations this study examines the use of a free breathing, black blood prepared fast spin echo technique in conjunction with T_2*-weighting at 3.0 T to generate BOLD contrast and T_2*-maps of the myocardium free of distortions, with the ultimate goal of applying this approach to the assessment of myocardial perfusion deficits.

Methods:

The proposed cardiac triggered imaging technique starts with a double IR module for ventricular black blood preparation (4) followed by a navigator module for respiratory motion compensation (5). T_2*-weighting was achieved by implementing displaced UFLARE (6, 7) using an extra evolution time τ between the initial excitation pulse and the first refocusing pulse (Figure 1). Phantom and volunteer studies were performed using 6- and 32-element cardiac coil arrays at 3.0 T (Philips Achieva, Best, Netherlands). Images were acquired with: scan matrix 256×256, FOV 350 mm, echo train length 20, TR=2 R-R intervals, slice thickness 8 mm. For comparison, EPI (TE=10ms, echo train length 15, no black blood preparation) was performed to examine geometrical distortions and image quality. T_2*-maps were generated from displaced UFLARE images of an oil filled phantom with τ ranging from 0 to 46 ms. For comparison a multi echo gradient echo approach was employed (TE=2-48 ms).

Results:

The images of the test object in Figure 2 demonstrate the geometrical integrity of the UFLARE image. Conversely, the EPI images revealed distortions of up to 1 cm. Figure 3 depicts T_2*-maps derived from (i) UFLARE and (ii) multi echo gradient echo data sets. T_2* values of the oil were found to be approximately 16.0 ms for multi echo gradient echo and approximately 14.0 ms for UFLARE data sets. Figure 4 (left) depicts a short axis view demonstrating the quality of the images obtained with free breathing, double-IR prepared, T_2*-weighted UFLARE in a volunteer study. Image quality, SNR and blood suppression are suitable for clinical applications even for strong T_2*-weighting ($\tau \geq 10$ms) at 3.0 T. Images are free of distortions due to B_0-inhomogeneities and free of physiological motion artifacts. For comparison, EPI-images of the same subject (Figure 4 right) exhibit distortions typical of EPI, which introduce the risk of misinterpretation of clinical images.

Discussion and Conclusions:

The feasibility of robust T_2*-weighted fast spin echo imaging, and the image quality advantage over the conventional EPI approach have been demonstrated. Spin echo based cardiac BOLD imaging holds the potential to obviate the need for contrast agents to assess myocardial perfusion, while avoiding the drawbacks of EPI and gradient echo based imaging. The proposed spin-echo based cardiac BOLD approach promises to extend the capabilities of cardiovascular MRI, to include mapping and quantification of myocardial iron content, assessment of endothelial function, detection of stress induced angina pectoris, and differentiation of arteries and veins, which have all been elusive hitherto. In conclusion, we anticipate the extension of this work (i) to examine its applicability for the detection of myocardial perfusion deficits in animal models and humans and (ii) to evolve towards three-dimensional, distortion free, cardiac BOLD imaging in concert with parallel imaging and T_2* mapping.

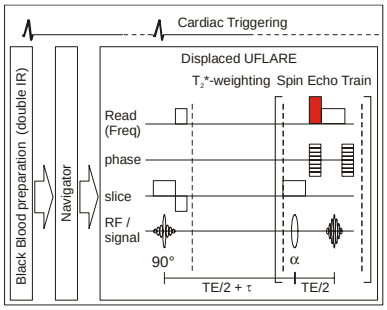

Figure 1: Cardiac and navigator gated, black blood prepared UFLARE. T_2* weighting is generated through the freely selectable delay τ, between excitation and the first refocusing RF pulse (α).

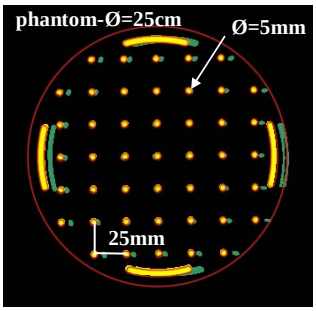

Figure 2: T_2^*-weighted images overlaid on a contour plot of the test object (red): UFLARE (yellow) and EPI (green).

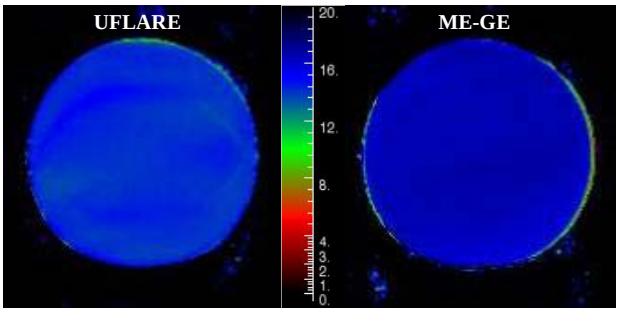

Figure 3: T_2*-maps of an oil filled test object scanned with the UFLARE sequence **(left)** and a multi echo gradient echo **(right)** technique.

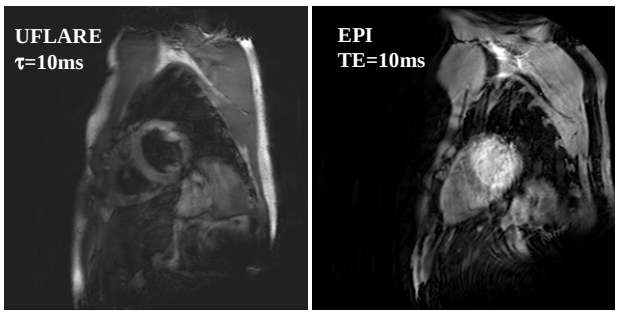

Figure 4: Short axis views derived from free breathing UFLARE using T_2*-weighting (τ=10ms) and black blood preparation **(left)** and breath-hold EPI of a healthy subject **(right)**.

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