Self-gated, reduced field-of-view diffusion tensor imaging of the human heart at 3.0T

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Introduction:
Myocardial fiber structure correlates with anisotropy in the water self-diffusion of the myocardium (1) which can be assessed using diffusion tensor MRI. In vivo measurement of myocardial diffusion proves to be difficult due to cardiac bulk motion, respiratory motion, chemical shift and susceptibility gradients around the heart. The purpose of this work was to investigate bipolar diffusion-encoding combined with zonal single-shot echo-planar imaging of the in-vivo heart at 3.0T.

Methods:
The gradient lobes in the standard Stejskal-Tanner experiment were replaced with bipolar gradients to zero out the first gradient moment of the diffusion gradients. The effect of flow-compensated diffusion gradients was simulated using cardiac motion parameters derived from tagging data of the heart (2). Figure 1 displays phase dispersion per unit distance for different b-values and relative time points within the systolic window for non- and flow-compensated diffusion encoding waveforms. It is seen that the motion sensitivity of the sequence with flow-compensated encoding gradients is reduced by a factor of about 10 during the second half of systole relative to the phase created by non-compensated encoding. This insight allows to optimally set the trigger delay and shot length to reduce signal loss from cardiac motion (3).

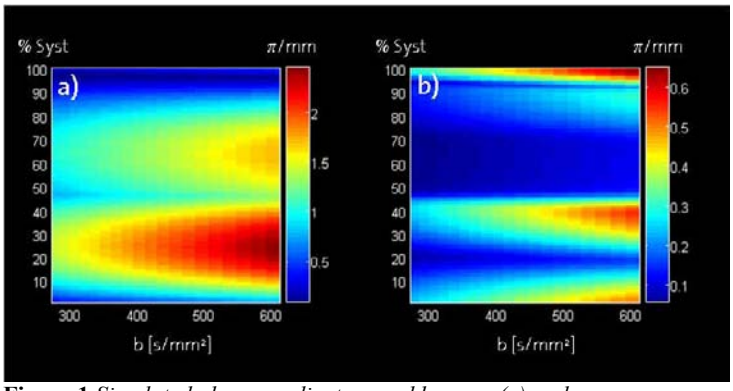

Figure 1 *Simulated phase gradient caused by non- (a) and flow-compensated (b) diffusion gradients at different trigger delays (vertical axis) during systole for different diffusion sensitivities (horizontal axis)*

To reduce the sensitivity of the sequence to off-resonances the echo-train length of the single-shot EPI acquisition was shortened by setting the slice-select gradient of the excitation pulse perpendicular to the echo pulse slice-select gradient (4) with a resultant reduction of the field-of-view covering the myocardium only. In addition, localized second order shimming was used (5). The measurements of the reference image and the 6 diffusion weighted images were performed during free breathing using a simple self-gating approach. In reconstruction only the images acquired in expiration were selected for averaging and diffusion calculation (6). Image selection was done using a correlation threshold. The measurements were performed on a 3.0T Philips Achieva whole body MR system (Philips Medical Systems, Best, NL) equipped with 80 mT/m gradients, using a 6-element coil array. Imaging parameters were: FOV=320 x 62 mm^2, resolution=2.2 x 2.2 x 6 mm^3, TE=67 ms, α=90°, b=350 s/mm^2. The cardiac trigger delay was set to ~75% of end systole. The eigenvectors of the resulting diffusion tensor were calculated using MATLAB (The MathWorks, Natick, MA, USA).

Results:
A representative diffusion weighted image of the left ventricle with reduced FOV is shown in Figure 2a). No signal loss from cardiac motion is observed despite the relative large cardiac bulk motion (~1.0 mm) during diffusion encoding. The direction of the largest eigenvector is shown in Figure 2b), revealing the circumferential orientation of the heart muscle fibers (7, 8, 9).

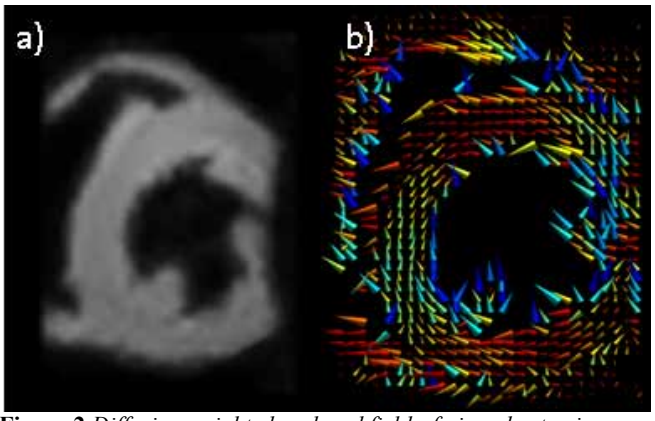

Figure 2 *Diffusion weighted, reduced field-of-view short axis slice (a) and calculated color coded principal eigenvectors (b)*

Discussion:
The proposed combination of reduced field-of-view imaging with bipolar diffusion encoding gradients at 3.0T allows in vivo diffusion weighted imaging of the human heart at high resolution.

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