Preventing Signal Dropouts in DWI Using Continous Prospective Motion Correction

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Introduction: Diffusion weighted imaging (DWI) has become indispensable in clinical routine, especially due to its sensitivity to early stages of brain ischemia. Patient motion during measurements is a major source of artifacts. A distinction must be made between motions during the acquisition of a single diffusion encoded image (intrascan) and movements in between these images (interscan) as well as between in-plane and through-plane motion [1]. In-plane motion in between scans can be corrected retrospectively by realigning the images, correcting the phase shift and applying a b-matrix rotation [2, 3]. For through-plane motion these methods fail since the measured object is inconsistent. It has been shown that prospective motion correction can correct for both types of interscan motion using navigators [4] or an external tracking device [5]. However, intrascan motion remains problematic. Even for single-shot EPI intrascan motion can lead to severe signal dropouts. Movements during diffusion encoding and between refocusing pulses can result in severe artifacts making it impossible to apply retrospective correction methods. This work presents a new method where prospective motion correction is continuously applied during the diffusion gradients to correct for six degrees of freedom intra- and interscan motion.

Methods: All experiments were performed on a 3 T Magnetom Trio (Siemens Healthcare, Germany) using an optical tracking system (ARTtrack3, Advanced Real-Time Tracking GmbH, Germany) for prospective motion correction. The twice-refocused SE-EPI sequence with diffusion weighting (Fig.1) was modified in two steps. First, prospective motion correction was enabled once per slice excitation. In a second step, the diffusion gradients were split into small 2 ms segments. During the execution of each segment, the subsequent one is prepared, including new position information if available. This allows for the continuous correction of intrascan motion. In the following human experiments the head motion of a healthy volunteer was tracked using a mouthpiece with reflective markers. In the measurement presented 11 slices (matrix 110×110, voxel size 2×2×2mm, TR = 6000ms, TE =94ms) were acquired with different b-values (b0, b1 =500, b2 =1000s/mm²) and three weighting directions each (trace weighting). For illustrative purposes, a simulation of the corrected gradients during head rotation was performed and is shown in Fig.1.

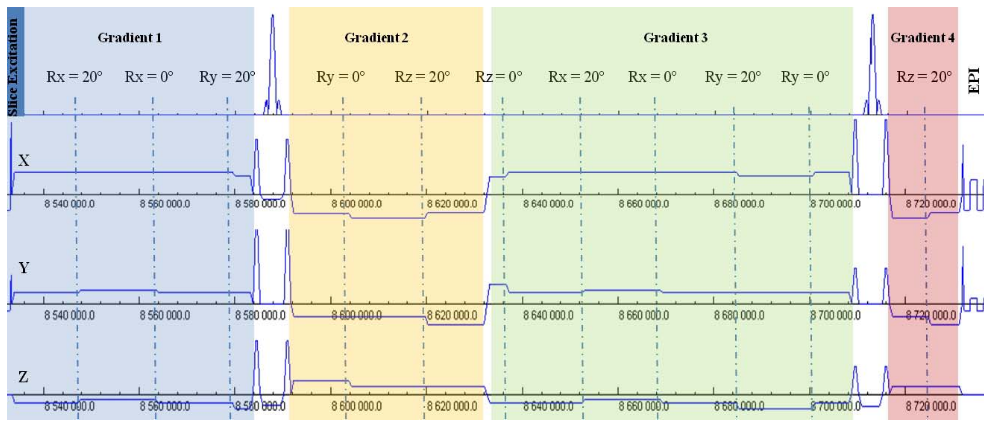

Fig. 1: Simulation of the RF pulses and the gradients in x, y and z during diffusion encoding. Several rotations of 20 deg. around each axis (Rx, Ry, Rz) were included in the simulation.

Results: Fig. 2 shows 10 slices with one diffusion weighting (b1 =500s/mm²). In the first line an experiment with no deliberate motion was performed for reference. In the second experiment the volunteer performed head movements. This motion was corrected prospectively for each slice excitation. The third row in Fig.2 shows an acquisition of the same imaging volume with a comparable amount of motion. In this case all gradients were corrected continuously. The motion plotted in Fig. 3 shows the position data from the tracking system during the third measurement.

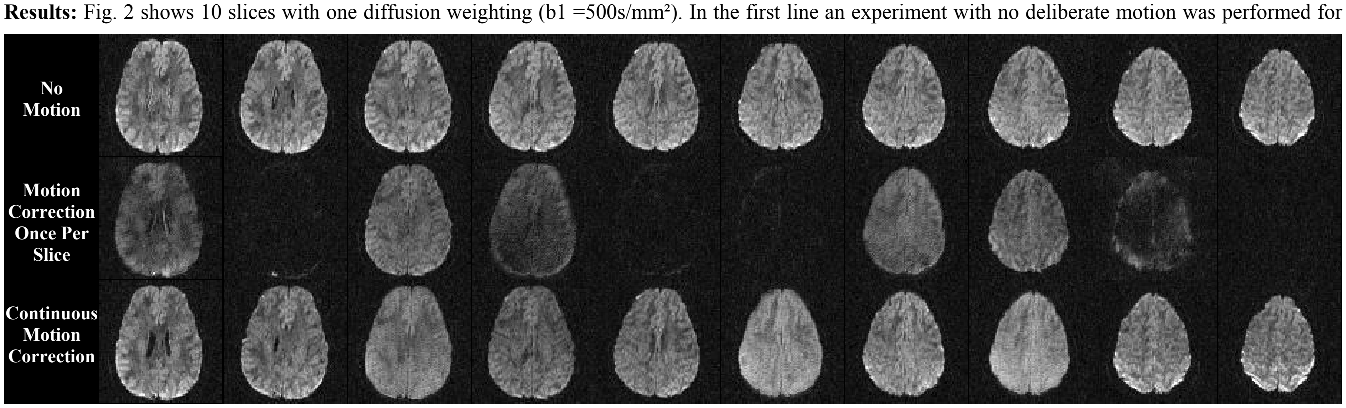

Fig. 2: Measurement with no motion (top row) and two with a comparable amount of motion, applying motion correction once per slice (middle row) and continuously correcting gradients (bottom row). 10 of 11 slices are shown.

Discussion: Motion correction for the slice excitation restores the alignment of the particular imaging volumes, but does not correct for intrascan motion. This leads to significant artifacts over the whole measurement and complete signal dropouts in about 50% of the images. The continuous correction of all gradients reduces these artifacts considerably even during strong head motion (in plane: 40 mm, 30 deg., out of plane: 10 mm, 6 deg). A noticeable difference between the 'no motion' and the 'continuous correction' images is the signal change in CSE-filled brain regions (Fig. 2, first slice). These signal losses are probably a result of changing flow characteristics associated with the extreme head movements and will be further investigated.

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References: [1] Trouard et al., JMRI 1996 [2] Leemans et al., MRM 2009 [3] Rohde et al., MRM 2004 [4] Lee et al., MRM 2005 [5] Aksoy et al, ISMRM Motion Correction Workshop 2010

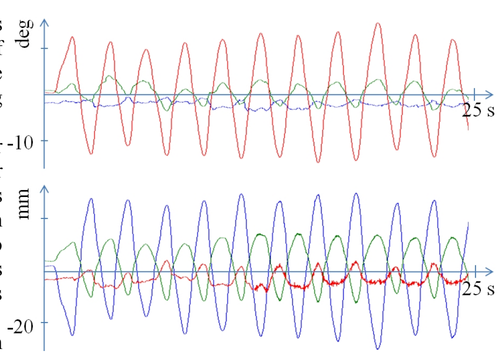

Fig. 3: Motion data during the first 25s of the third measurement. Rotations around Rx (blue), Ry (green), Rz (red) and translations in x (blue), y (green), z (red).