Motion robust high resolution FLASH

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Introduction: It has been shown in recent studies that the 2D T2* weighted spoiled gradient echo sequence (FLASH) [1] is able to detect cortical lesions at high field strengths, even with a higher accuracy compared to the Double Inversion Recovery (DIR) sequence [2]. In the current implementation, 2-3 slabs consisting of twenty 1mm slices are acquired to cover the supratentorial brain, resulting in a scan time of 8minutes/slab. These long acquisition times increase the likelihood of motion during acquisitions, which makes the acquisition of high-resolution images with this method infeasible in uncooperative subjects (such as children). To solve this problem, in this work we propose a novel motion robust high-resolution FLASH acquisition scheme. This scheme is based on acquiring multiple low-resolution images with different orientations and then combining these acquisitions into an isotropic high-resolution image using super-resolution reconstruction. We use a motion sensor [3] to identify the low-resolution images corrupted with motion to reacquire them, as well as to correct for the motion between the low-resolution acquisitions. The sequence was tested on 3 volunteers and images with isotropic resolution of 0.6 mm were reconstructed with a total scan time of 20 minutes.

Methods:

Image Acquisition: The low-resolution acquisitions consist of 3 orthogonal directions as well as 6 oblique orientations with 45 degrees between axes (see Figure 1). This particular sampling scheme was used in order to reduce the scan time for each acquisition while maintaining good k-space coverage. FOV for each acquisition was 200x200mm^2 with 330x330 matrix. Forty four slices were acquired with a slice thickness of 4mm. The gradient echo images had a TR/TE of 1000ms/20ms, and readout bandwidth of 300Hz/Px. GRAPPA with 6/8 PF was applied to reduce acquisition time of each shot (2 minutes/shot). Experiments were performed with a 32-channel head coil on a 3T Siemens TRIO scanner. Three healthy volunteers were scanned with this sequence. Each volunteer was scanned two times, and was ordered to stay still for the first scan and move 3 times for the second scan.

Motion detection and reacquisition strategy: We used electromagnetic sensors built by Robin Medical Inc. that showed accurate motion tracking results in a previous study [3]. The sensor data was used in our study to detect the occurrence of significant motion to enforce re-acquisition of the distorted LR images. Also the motion parameters obtained from the sensor were used to match the phase and orientation of each acquisition in 3D k-space.

Image reconstruction: We applied a k-space reconstruction approach where the k-space data from each low-resolution shot is transformed to a 3D k-space domain with an assumption that the slice profile is Gaussian. Once the 3D k-space is filled with all the data, a DCF function was calculated as in [4] (on a spherical FOV) followed by an inverse non-uniform FFT [5].

Results: Figure 2 shows sample reconstructions from one of the volunteers, where the adult volunteer was ordered to stay still in Figure 2a, (no movement above the predefined threshold was detected by the motion sensor). Figure 2b shows reconstructions from the same volunteer where the volunteer was ordered to move during the scan. Figure 2c shows the reacquisition method applied to this data set where 3 more datasets (reported by the motion sensor) were acquired. PSNR compared to the Figure 2a has been improved from 28.3 dB (Figure 2b) to 36.54 dB (Figure 2c).

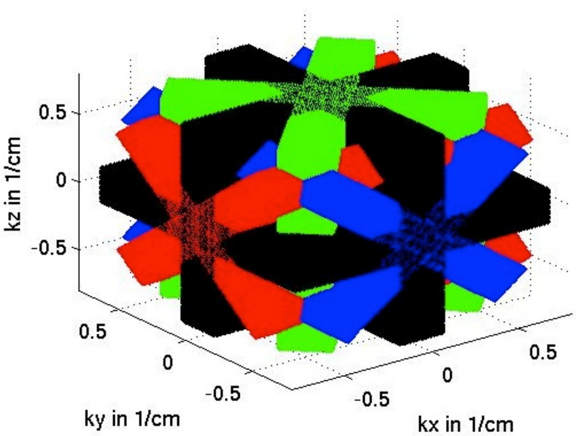

Figure 1, shows the 3D k-space representation of the proposed acquisition. Black slabs show the 3 orthogonal orientations. Blue, green and red slabs show the oblique orientations acquired.

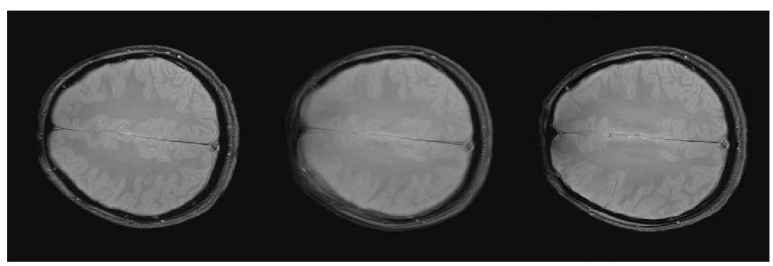

Figure 2 (left) shows a high resolution GRE image reconstructed from a study where no motion above the threshold was detected, Figure 2 (middle) shows a study where the patient moved 3 times during the scan, Figure 2 (right) shows the output of the motion correction using this data.

Discussion and Conclusion: As can be seen in Figure 2, with the proposed acquisition scheme it was possible to reconstruct high quality images from multiple low-resolution images even when there was substantial motion. This method can be used to get high-resolution images from subjects that are able to stay still in the scanner for shorter scan times (1-2 minutes) but not for the whole acquisition (20 minutes).

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