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Prospective motion correction with FID-triggered image navigators

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INTRODUCTION: The aim of this study is to show the potential of combining short free-induction-decay navigators (FIDnav [1]) and image navigators (IMGnav [2,8]) to mitigate motion effects in brain MRI exams. FIDnavs with a duration of 200 µs are employed to monitor motion and, when detected, to trigger the acquisition of a low-resolution image navigator volume for co-registration to a reference. In this implementation, the obtained head motion parameters are subsequently used to prospectively correct for head movements.

MATERIALS AND METHODS: The prospective motion correction functionality was implemented in a prototype MP-RAGE sequence. An FIDnav was sampled (64 points in 0.2 ms) after an additional non-selective excitation pulse (α_{FID}=9°) at the end of the GRE block of the MP-RAGE sequence (TI_{FIDnav} = 1532 ms, TI/TR/TE/α/TA = 900ms/2300ms/2.86ms/9°/5:21min, echo-spacing 7 ms, matrix 256x256x176, 1.0 mm^3 isotropic). The FIDnav signal was used online to monitor motion: exceeding an empirical threshold triggers the acquisition of a low resolution image navigator (IMGnav) in the next repetition and the motion corrupted repetition is reacquired immediately. The IMGnav used a recently proposed multi-echo segmented 3D-GRE [3] with a cylindrical k-space sampling pattern (α/TA = 9°/1.2sec, echo-spacing 7 ms, 6 echoes, matrix 64x64x32, voxel size 4.1x4.1x6.0 mm^3). Its parameters were specifically designed to acquire a whole-brain volume with the same properties as the GRE block of the MP-RAGE with respect to the acoustic noise and impact on longitudinal magnetization (wrt. the number of excitations in the GRE block). After obtaining written consent, 5 healthy volunteers were scanned at 3T (MAGNETOM Verio, Siemens AG, Erlangen, Germany) using a commercial 32-channel head coil. The subjects were instructed to change their head position three times during a scan upon verbal commands and to follow frequently observed motion patterns [4]: translation in head-feet direction, head nodding, and shaking. These scans were repeated by having the motion correction turned on and off. Two additional datasets (I, II) without voluntary motion and with motion correction turned off were acquired for each subject, resulting in a total of 40 MP-RAGE volumes. For the detection of rapid and slow head movements, a scalar FIDnav value was calculated by combining the signals from all coil elements. Rapid motion at a time point t is observed by signal changes as compared to the preceding repetition at (t-1), whereas slow movements at time t are reflected by FIDnav changes as compared to the first repetition of the scan. An empirical threshold of 8% for fast movements and 5% signal change for slow movements was chosen to trigger the acquisition of an IMGnav. The IMGnavs were co-registered in real-time to obtain the new position of the head using PACE [5]. To assess the performance of our correction in several brain regions, volumes of grey matter (GM), white matter (WM) and total intracranial cavity (TIV) were measured on each 3D volume using an automated morphometry package [6]. The segmentation results of the scans (i) with motion and correction, (ii) with motion but without correction, and (iii) without motion and without correction were compared to the reference without motion and correction II. Further, a quantitative image quality assessment [7] was performed on all 3D volumes.

RESULTS AND DISCUSSION: Qualitative improvements (less blurring and ghosting) were visually observed in all corrected images (one illustrative case can be seen in Figure 1a). The chosen FIDnav threshold triggered the acquisition of the IMGnav reliably; however in periods where the subject was asked to stay still, some triggering events occurred, indicating that the chosen thresholds might require further optimization. A specificity of 97% and a sensitivity of 100% were observed for the triggering, considering true motion to occur only when a verbal command was given to the subject. It should be noted that the total scan time is prolonged by two TRs if motion is detected (for the IMGnav and reacquisition of the corrupted TR). We observed translational motion up to 11 mm and up to 9 degrees. Quantitative evaluation comparing segmentation results revealed that the discrepancy in volumes to the non-motion measurements could be significantly reduced in our experiments by 2% for TIV and by 3.6% for WM (wrt. the respective volumes at rest) by applying the proposed motion correction methodology (Figure 1b). The mean quality index (QI) could be reduced from 1.01 to 0.86 which demonstrates that higher image quality is achieved with our correction.

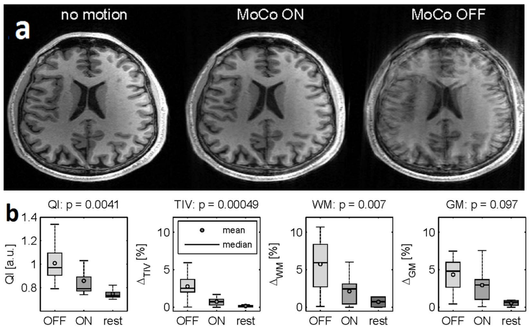

***Figure. 1 (a)** Axial views of motion correction results for head shaking; **(b)** Changes in volumetric measurements and image quality due to motion correction). The p-value is shown as calculated with the Wilcoxon rank-sum test when comparing the volumes with and without correction.*

CONCLUSION: The present approach extends recent work on MR-based motion correction [8] in the sense, that motion is monitored with practically no penalty (fast, low-impact FIDnavs) and the imaging navigators are employed only when needed without influencing the magnetization profile of the host sequence. Qualitative and quantitative improvements of image quality are evident in the studied cases. Such a concept may be extended to other imaging protocols as already proposed in [9] and has the potential of providing a very efficient MR-based motion correction technique. Remaining limitations of this approach are the choice of appropriate thresholds for the FIDnavs, the limited registration accuracy as well as the extra scan time of the FID-triggered IMGnav. Future work will aim at the implementation of an automated FIDnav threshold adaptation and at reducing the scan time overhead due to IMGnav acquisition through a motion prediction approach as proposed in [10].

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