3D FatNav: Prospective Motion Correction for Clinical Brain Imaging

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Target audience

Researchers and clinicians interested in prospective motion correction for brain imaging.

Purpose

Clinical brain MRI often suffers from motion artifacts, not the least for patients with pain, larger brain damages or children. Several pulse sequences can handle motion better, including PROPELLER[1] and EPI, both of which can be combined with retrospective motion correction in the image reconstruction. Several prospective motion correction techniques have been developed recently, either using an MR navigator such as PROMO[2], or external hardware[3]. This work details the extension of our previously described FatNav[4] navigator from 2D to 3D.

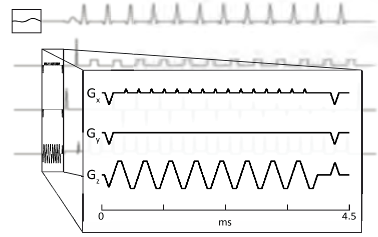

Figure 1 Pulse sequence diagram of a 3D FatNav sequence in an arbitrary imaging sequence

Methods

All scans were performed on a clinical 1.5T scanner (Discovery MR450, GE Healthcare, Waukesha, WI) with a standard 8-ch head coil. The 3D FatNav comprised a highly accelerated EPI readout placed after a fat saturation RF pulse, as illustrated in Figure 1. Parameters for the 3D FatNav module: FOV = 320×320×320 mm^3, matrix = 32×32×32, TE = 6 ms, T_{seq} = 4.5 ms (excl. RF pulse). The navigator was accelerated two times in the ky direction, $R_y = 2$, and eight times in the kz direction, $R_z = 8$. Combined, this yields a total acceleration factor of $R_{tot} = 16$ (using an 8-ch RF coil). This high acceleration factor was possible due to the sparsity of the fat signal[4]. The navigators were collected in a multi-shot fashion, i.e. one kz-plane acquired per excitation; hence four excitations were needed to collect a 3D navigator volume using this acceleration. A fully sampled navigator volume was acquired for ghost correction and parallel imaging calibration, and served as a reference image volume for motion estimation. Each new 3D-FatNav volume acquired was reconstructed, aligned to the reference image volume, and the associated 3D rigid body motion estimates were returned to the running main imaging sequence. Acquiring the navigator volume, reconstructing and aligning it takes ~250 ms, giving an update rate of ~4 Hz. With the high acceleration factors used, the navigator sequence time became very short, hence the total scan time for the entire imaging scan was only slightly increased, <10% for a normal clinical T1-w scan.

Figure 2 Iso surface 3D FatNav volume

Two sets, one with fat saturation and one without, of four scans each were acquired on a healthy volunteer, which was instructed to lie still on the first two scans, and then move the head in a controlled fashion for the following two scans. 3D FatNav data were acquired for all four scans, but the pulse sequence update was only activated for the second and fourth scan. Parameters for the spin echo based main imaging sequence were: FOV/slice thickness/TE/TR = 28cm/5mm/11ms/450ms.

Results

Figure 4 and Figure 5 shows T1-w images with and without fat saturation, respectively. The images from the scans where the subject was not moving have similar image quality, meaning that using 3D FatNav for a stationary patient does not have a negative impact on the image quality. Figure 4 bd and Figure 5 bd show that the image quality is significantly increased using prospective 3D FatNav correction for a moving subject..

Figure 3 Reformats, 3D FatNav (R=16)

Discussion

Our proposed prospective 3D FatNav module was in this work shown to be able to address 3D head motion using a very short navigator duration. In this work, we have built up the 3D FatNav volume over four excitations to avoid any geometric distortions in the slice (z) direction. 3D FatNav can also be acquired in one excitation, within a 20 ms duration. This would trade-off further efficiency to potential bias in the motion estimates due to distortions. In any case, a full 3D volume within this short time allows 3D FatNav to be combined with a variety of pulse sequences. If fat saturation is not desired, 3D FatNav can still be used but with a very low flip angle of the excitation pulse Future research will include exploring and quantifying the accuracy of motion estimates. The recon and processing time for the navigators can also be further decreased.

Conclusion

3D FatNav is easily implemented on clinical scanners with standard RF coils, does not require any extra hardware, and will increase the image quality for moving patients without significant scan time increase.

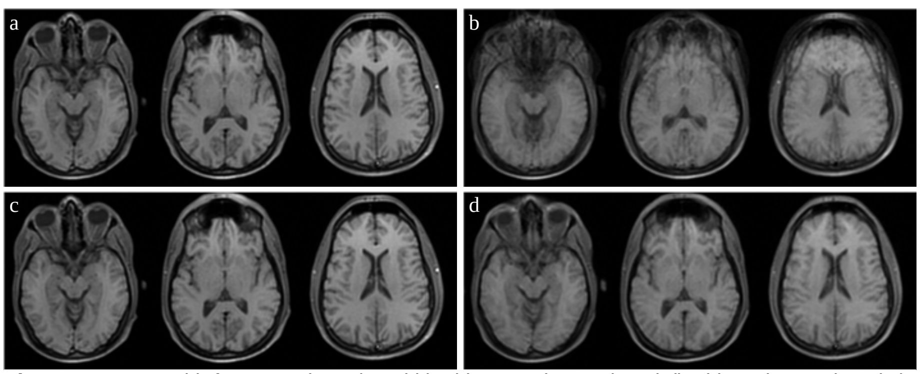

Figure 4 Images with fat saturation, a) and b) without updates, c) and d) with updates, a) and c) without motion and b) and d) with motion

References

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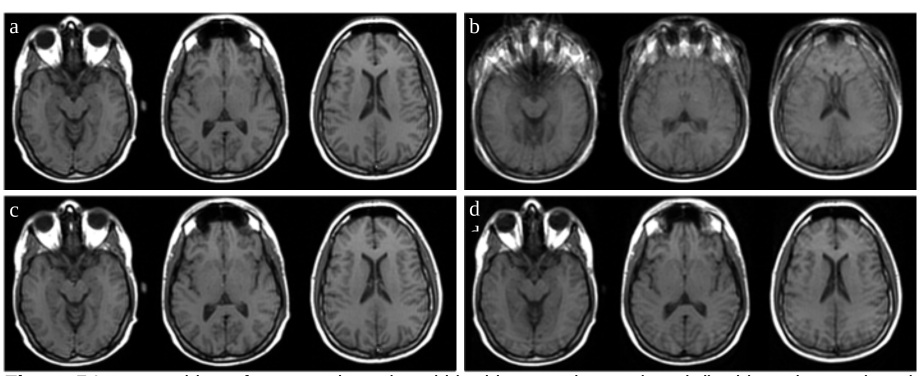

Figure 5 Images without fat saturation, a) and b) without updates, c) and d) with updates, a) and c) without motion and b) and d) with motion