Dynamic 3D T1 TFE Images of the Orbit with High Spatiotemporal Resolution at 3T

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Introduction: Dynamic imaging of the orbit during eye movement with high spatiotemporal resolution is possible using a segmented acquisition synchronized with the gaze target motion.[1] Nevertheless, the excessively long resulting scantime prohibits clinical use. Therefore, methods are needed to decrease the examination duration, such as, e.g., higher B0 field strength to decrease the number of necessary signal averages. Also, the use of a multichannel receive array will enable simultaneous scanning of both orbits and kt SENSE accelerates image acquisition.

Due to the neighboring oral cavities, good shimming is also necessary to avoid signal dropout and image distortion. Simultaneous eye tracking will enable the control of the reproducibility of the eye motion, and may be used for rejection and re-measurement of k-space profiles with wrong gaze direction.

We present here several methodological improvements that enable dynamic imaging of the orbit with high spatiotemporal resolution at 3T.

Methods: On each eye we placed, so that the subject was able to see through, a two channel microscopy coil, 47 mm in diameter (Philips Research; Hamburg, Germany) on a 3T Philips Achieva scanner. kt SENSE with acceleration factor from 4 to 6 was used to decrease acquisition time. The flip angle (9°) of the segmented 3D T1 TFE sequence was signal optimized. Other scan parameters are: 15 to 25 time frames of 100 ms duration, 38 over-continuous slices. TE 4.4 ms, scan duration 5 to 8 min, no signal averaging. A field of view of 120x120x30 mm^3 was used to avoid foldover artifacts. Readout direction was AP and a scan percentage of 66% was used to shorten scantime: scan matrix 300x192x19.

B0 map (3D T1FFE, 20 s scantime, TE 2 and 4.43 ms) based shimming was performed using a rectangular shim volume including both orbits.

The horizontal sinusoidally moving gaze target (red dot, 2s period, peak velocity 64°/s, amplitude ±20°) was projected on a screen with a laser system with 500Hz position update. The motion of the target was synchronized with the scanner acquisition. The tracking of the eye movement was achieved by infrared video recordings at 500Hz with an eyelink2000 system (SR Research, Mississauga, Ontario, Canada).

Results: The multichannel microscopy coil enables the simultaneous scanning of both orbit with a good SNR. The phase encoding in the RL direction was efficient in preventing motion artifacts from spreading over the orbit. With kt SENSE acceleration factors of 5 and 6 saturation bands can be seen within the orbit (Fig 1 left panel), with acceleration factor of 4 these bands were outside of the orbit (Fig 1 middle and right panel).

The 500Hz update of the gaze target gave the impression of a continuously moving target. This could not be achieved with a normal 60 Hz video projector. The reproducibility of the eye motion drops continuously over the acquisition duration: outliers become stronger and more frequent (Fig 2).

The ability of different subjects to follow fast moving targets varies strongly and impacts the final image quality. Even within one scan the following performance varies for different time frames, which results in different image quality (Fig 1 middle and right panel and Fig 2 left panel)

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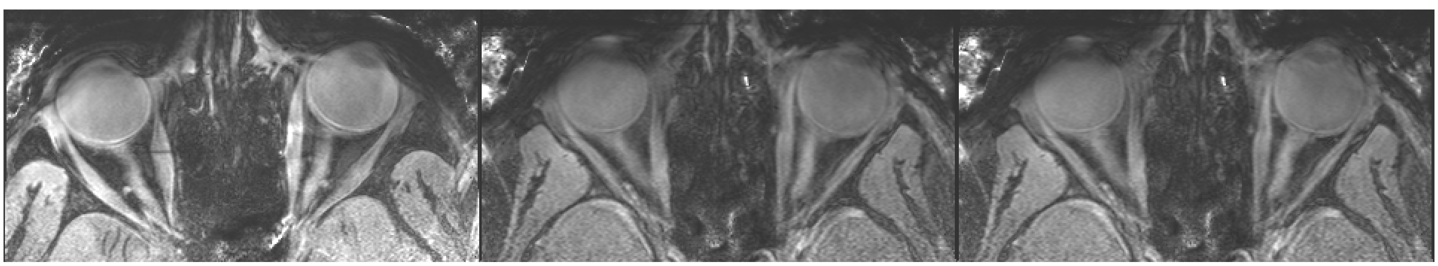

Figure 1: *T1 weighted gradient echo images of both orbit during periodic eye movements (Left Panel) kt SENSE factor 5, Slice 17 of 38, time frame 7 of 15, trained subject: the image blurring due to imperfect motion periodicity is small.(Middle Panel) kt SENSE factor 4, slice 19 of 38, time frame 6 of 20, untrained subject. The lower kt SENSE factor let the artifact saturation bands disappear. The image blurring due to imperfect motion periodicity is relevant. (Right Panel) kt SENSE factor 4, slice 19 of 38, time frame 1 of 20, untrained subject, time frame with a lower deviation from the median eye position. The blurring is decreased.*

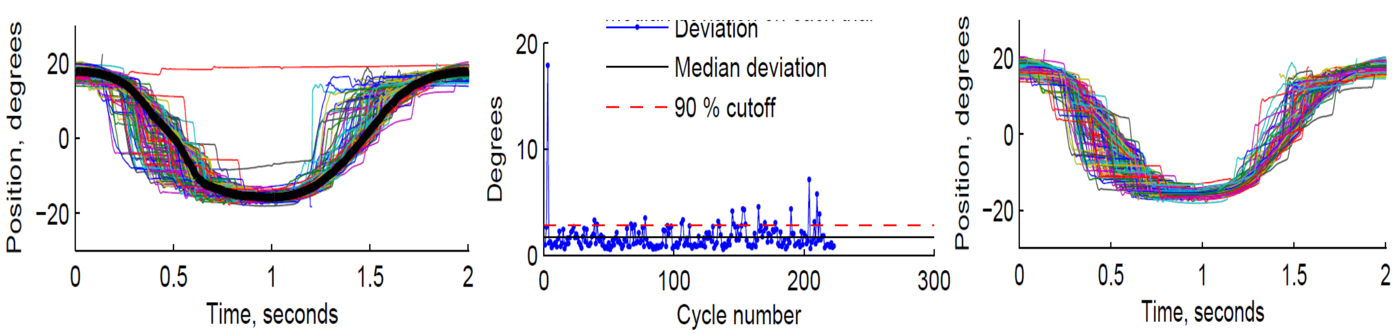

Figure 2: *Untrained subject: (Left Panel) Eye position traces over the 220 cycles. In black: the median eye movement. (Middle Panel) The average deviation from the median trace is reported for each cycle. The median deviation and the cutoff for the 10% worst outliers are shown. (Right Panel) Traces of eye position over the 200 best cycles.*

Conclusion: We have proven the feasibility of high spatiotemporal resolution dynamic MRI of the orbit at 3T, in a scantime comparable to one frame of high resolution static images. The quality of the images is much better than those obtained with real time imaging.[2] The eye motion reproducibility is dependent upon motivation and training of the subjects and strongly impacts the final image quality. Tracking of eye position allows cycles with bad motion and speed accuracy to be discarded, and the potential rescanning only slightly increases the overall scantime (Fig 2).

References: [1] Piccirelli M, et al. Proc. ESMRMB 2005 http://dx.doi.org/10.1594/ESMRMB05/418 [2] Berg, I, et al. European Radiology 2011 http://dx.doi.org/10.1007/s00330-011-2232-1