Prospective motion correction to increase the achievable resolution in brain imaging at 7T

Peter Schulze[1], Daniel Stucht[1], K. A. Danishad[1], Ilja Y. Kadashevich[1], Michael Herbst[2], Cris Lovell-Smith[2], Julian Maclaren[2], Robb T. Barrows[3], Todd P. Kusik[3], Brian S. Armstrong[3], Tom Prieto[4], Thomas Ernst[5], Maxim Zaitsev[2], and Oliver Speck[1]

[1]Department of Biomedical Magnetic Resonance, Otto-von-Guericke University, Magdeburg, Germany, [2]Department of Radiology, University Medical Center, Freiburg, Germany, [3]Department of Electrical Engineering and Computer Science, University of Wisconsin-Milwaukee, Milwaukee, United States, [4]Department of Neurology, Medical College of Wisconsin, Milwaukee, United States, [5]Department of Medicine, University of Hawaii, Honolulu, United States

INTRODUCTION

High field MRI systems, such as 7T, have a higher signal to noise ratio (SNR) than lower field scanners, and thus allow for higher spatial resolution. However, high resolution scans may require long acquisition times, which in turn increase the risk of subject motion. Even with a co-operating and trained subject, involuntary motion due to heartbeat, swallowing, respiration and changes in muscle tone can cause image artifacts that reduce the effective resolution. Prospective motion correction at 3T and 7T has been shown to improve image quality in high resolution acquisitions [1-6]. In this study we present ultra high resolution in vivo MR images acquired at 7T using prospective motion correction during long acquisitions.

MATERIALS AND METHODS

Measurements were performed on a 7T whole body MRI scanner (Siemens Medical Solutions, Germany). A 32-channel coil (Nova Medical, Wilmington, MA, USA) was used for data acquisition. Volunteers were instructed to minimize head motion. The involuntary motion of the subject's head was tracked by an external optical tracking system using a moiré pattern target (MPT, University of Wisconsin, [7]) mounted on lightweight dental impressions. The tracking system was mounted in the bore at a distance of approximately 0.15m to the tracking target. Real-time correction was accomplished by recalculating the logical orientation of the gradients and frequencies according to the current position and orientation of the target prior to every excitation. The correction was applied during the scan and motion was logged for analysis. T1-weighted isometric 3D MRI data were acquired with an MPRAGE sequence; a GRE sequence was used for T2*-weighted multislice 2D MRI. Resolutions of 0.6x0.6x0.6mm³ or 0.5x0.5x0.5mm³ in 3D and 0.25x0.25x2.0mm³ or 0.25x0.25x1.0mm³ in 2D were achieved. Uncorrected MRI was performed prior to the motion corrected scans. For ultra high resolution MRI two data sets were averaged to achieve higher SNR. The acquisition times were between 14 and 30 minutes each, depending on the resolution and the number of averages.

RESULTS

Subject movement was consistently 2-3mm during scans, most likely due to muscle relaxation over the acquisition period. This amount of motion generates visible artifacts in the high resolution data (Fig. 1, 2). In contrast, the scans with prospective motion correction are virtually free of motion artifacts, even at this ultra high resolution (Fig. 3) [8]. Comparisons of uncorrected and corrected data and respective line profiles are given in Fig. 2.

DISCUSSION

Prospective motion correction with optical tracking requires very little adaption of the sequence and fully preserves the established sequence timing. All scans show marked improvement over the uncorrected scans (Fig 1-3). The gain of image quality is particularly pronounced in acquisitions with high resolution and long scan times. To our knowledge, this is the first demonstration of successful prospective motion correction at such high spatial resolution with consistent improvements even in co-operative subjects. The results demonstrate the possibility of in vivo MRI microscopy with potentially even higher resolution in a broader subject population. Residual artifacts in the image may result from pulsation, coil sensitivity profile changes and B1 changes due to head motion. The technique promises to become a standard feature of new MRI systems.

ACKNOWLEDGMENTS AND REFERENCES

This project is supported by BMBF INUMAC (01EQ0605) and NIH / NIDA (1R01DA021146 and K02-DA16991).

[1] Zaitsev M, et al.,2006, Neuroimage 31(3):1038-1050; **[2]** Zaitsev M, et al., 2008, ISMRM, #3114; **[3]** Stucht D, et al., 2009, ISMRM, #4607; **[4]** Qin et al., 2009, MRM 62(4):924–934; **[5]** Schulze P, et al., 2011, Proceedings MMT, #256; **[6]** Aksoy et al., 2011, MRM 66(2):366–378; **[7]** Armstrong B, et al., 2009, ISMRM, #4641; **[8]** Maclaren et al., 2010, MRM 63(1):162-170.

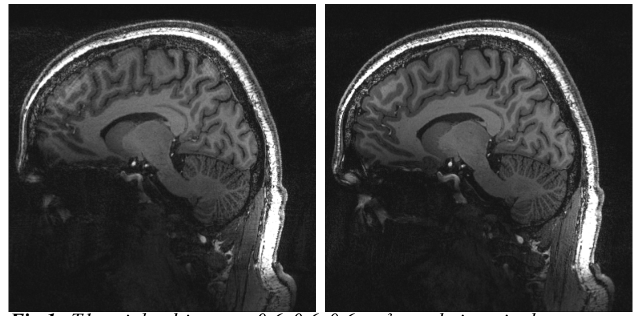

Fig.1 *T1-weighted images, 0.6x0.6x0.6mm³ voxel size, single average, TA ~14min each, left uncorrected, right motion corrected (similar subject motion in both scans)*

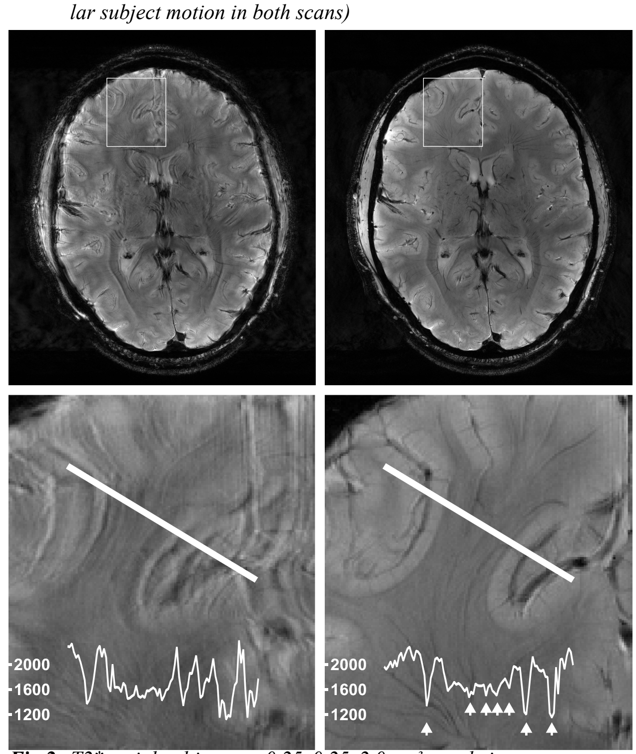

Fig.2 *T2*-weighted images, 0.25x0.25x2.0mm³ voxel size, two averages, TA ~23min each, left uncorrected, right motion corrected, bottom row: zoomed region and line profile. Note arrows which mark vessels not visible in uncorrected scan.*

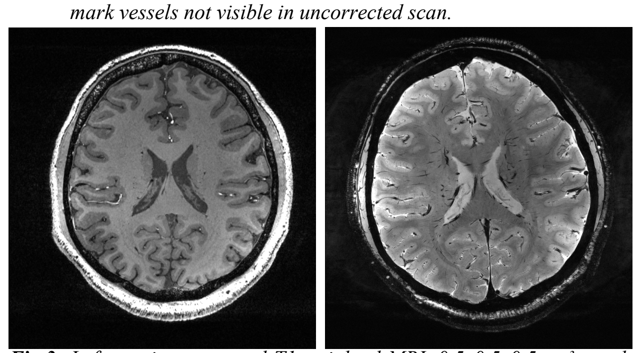

Fig.3 *Left: motion corrected T1-weighted MRI, 0.5x0.5x0.5mm³ voxel size, two averages, TA ~30min. Right: motion corrected T2*-weighted MRI, 0.25x0.25x1.0mm³ voxel size, two averages, TA ~23min, both scans are free of motion artifacts.*