Correction of breathing-induced artefacts in high-field brain MRI using concurrent field monitoring

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Introduction: In anatomical imaging, spoiled gradient echo sequences are widely used for many types of contrast, especially at ultra-high fields. In a recent study, poor image quality including ghosting and increased signal inhomogeneity, was observed in T2*-weighted images at 7T, in patients with Alzheimer's disease [1]. The observed artefacts were related to altered breathing pattern of the Alzheimer's patients compared to healthy controls, and were reduced by a navigator-based f_0-correction scheme. The underlying problem was identified as field fluctuation caused by the changes in susceptibility distribution that accompany breathing motion. An alternative method of observing such fluctuations is concurrent magnetic field monitoring with NMR probes [2,3,4]. Compared to navigators, the monitoring approach has the advantage that it does not require any alterations or extensions of the imaging sequence. It also distinguishes spatially uniform field changes from linear fluctuations, which can also readily be accounted for in image reconstruction. The aim of the present work was to explore these capabilities for the situation mentioned above, i.e., gradient-echo imaging at 7T under varying breathing patterns.

Methods

Imaging: A healthy volunteer was scanned on a 7T Philips Achieva system (Philips Healthcare, Cleveland, USA) using a 16-channel Nova Medical head receive coil. The volunteer was instructed to breathe normally, deeply or shallow during individual scans. Gradient echo images were acquired with the following scan parameters: TR 500ms, TE 15ms, flip angle 45°, FOV 26x26 cm, resolution 0.75x0.75mm, slice 2mm, resulting in a total scan time of 3 minutes. The same scan was monitored without the volunteer in the scanner, to record reference field evolutions not containing any breathing effects. Images were reconstructed based on the concurrently monitored evolutions as well as the reference evolutions for comparison. The reconstruction included demodulation of the imaging signals by zeroth-order field fluctuation.

Field monitoring: Four 19F NMR field probes were placed on the outside of the receive coil insert, in an approximately tetrahedral arrangement, so as to allow for monitoring of zeroth- and first-order magnetic fields with good conditioning. The probes were excited simultaneously with the magnetic centre of the proton excitation pulse, using a scanner-independent transmit chain. The signal from the probes was fed via T/R-switches into otherwise unused receive lines of the 32-channel MR system. To acquire fluorine signals with the proton receive channels, the carrier frequency was shifted by analogue RF diode mixers (ZX05-10L+, Mini-Circuits, USA) to the corresponding proton frequency expected by the spectrometer.

Results: As shown in Fig. 1, field fluctuations in the zeroth- and in the first-order head-feet (HF) and anterior-posterior (AP) directions were observed, which correlated strongly with the breathing pattern. The gradient term in the left-right (LR) direction showed no detectable breathing-related fluctuation, as expected due to the symmetry of the torso. During deep breathing, the f_0 variations were ~4 Hz, compared to less than 2 Hz during normal breathing. In both G_{AP} and G_{HF} the field fluctuations were on the order of 0.3 Hz/cm during deep breathing. Although the observed field fluctuations were somewhat less pronounced than those reported in Ref. [1], images reconstructed based on the reference field evolutions exhibited significant intensity modulations of low spatial frequency and increased ghosting (Figs 2&3) with deep breathing. These artefacts were suppressed to a large extent by considering the actual field evolutions obtained with concurrent monitoring. Images acquired during normal or shallow breathing showed good quality in both reconstructions.

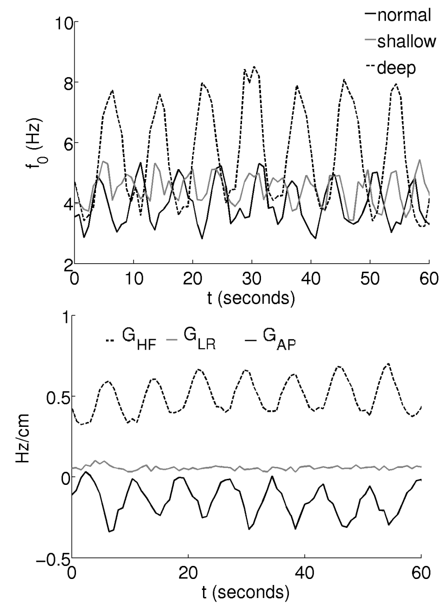

Fig 1: Monitored f_0-fluctuations from scans with different breathing patterns (top). Monitored first order fields, during a scan with deep breathing (bottom).

Conclusion: It has been shown that concurrent field monitoring is an effective means of observing and accounting for field fluctuations related to breathing in high-field imaging. Artefacts similar to those reported in Ref. [1] were successfully removed in this way. Unlike navigator-approaches, this is accomplished without sequence adjustments or added RF power deposition in the subject.

References: [1] Versluis et al., Neuroimage 2010, 51:1082-1088 [2] Barmet et al., 2008 Magn. Res. Med 60:187-197
[3] Barmet et al., Proc. ISMRM 2010, p.219 [4] Pavan et al., Proc. ISMRM 2010, p.1538

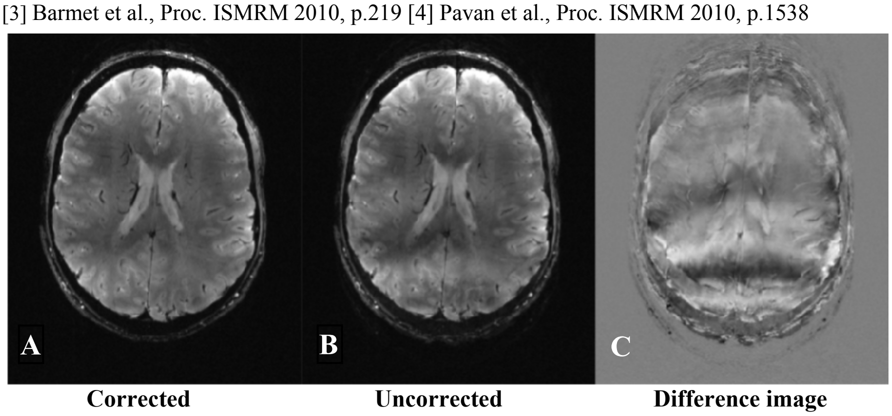

Fig 2 (Top): Image acquired during deep breathing, with reconstructions based on A) concurrently monitored trajectory, B) reference trajectory. C) Difference image
Fig 3 (Right): Comparison of concurrently monitored (left), and reference reconstruction (right), in two different image series, showing intensity variations (circle) and ghosting (arrow).