Feedback field control improves the accuracy of T_2* mapping at 7T

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INTRODUCTION
At high field strength T_2* weighted imaging suffers from artifacts due to field fluctuations caused by breathing motion[1]. Thereby the achievable accuracy of quantitative analysis such as for T_2* mapping can be heavily impacted. To correct for such fluctuations it has been proposed to use phase navigators[1,2] or magnetic field monitoring[3-5]. However such post-acquisition correction methods cannot restore inherent information loss, e.g. due to RF pulses being applied off-resonance or signal loss due to through-plane dephasing. Therefore we propose to employ real-time higher-order field control[6] based on NMR field sensors and dynamic shim actuation providing full 3rd order real-time field compensation. The system has recently been demonstrated to stabilize the field during MRI at 7T[6]. Thereby breathing artifacts in T2* weighted images could be effectively removed[6]. The aim of this work is to explore the utility of this approach for enhancing the accuracy of T_2* mapping.

MATERIAL & METHODS All measurements were performed on a whole-body 7T MR system (Philips Healthcare, Cleveland, USA) using a quadrature transmit head coil together with a 32-channel receive array (NOVA Medical, Wilmington, USA). To test the benefit of the method, T_2* maps of a phantom (liquids doped with CuSO4 to typical in-vivo T_2 values) were acquired using a 2D multi-echo gradient echo sequence (10 echoes, TE=3-33 ms, TR=400 ms, matrix=260x250, FOV=130x130 mm^2) with and without feedback field control. The field update rate was 10 Hz. Breathing related field perturbations were simulated by moving a water bottle (5 liters) periodically between 54 cm and 65 cm distance from the phantom along the z-direction. For reference the scan was repeated without field perturbations. The method was also tested in-vivo with a normally breathing subject. Five (in-vivo) and ten (in-vitro) repeated measurements with and without field feedback were recorded. In the in-vivo data the standard deviation of resulting T_2* estimates was analyzed for a selection of anatomical regions.

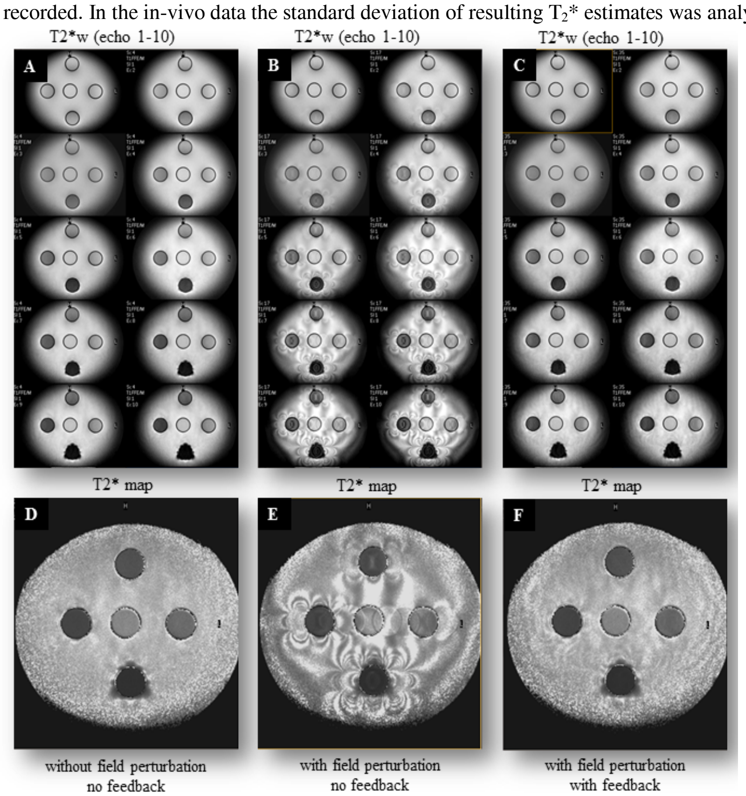

Figure 1: Phantom images. T_2* weighted images (a-c) and calculated T_2* maps (d-f)

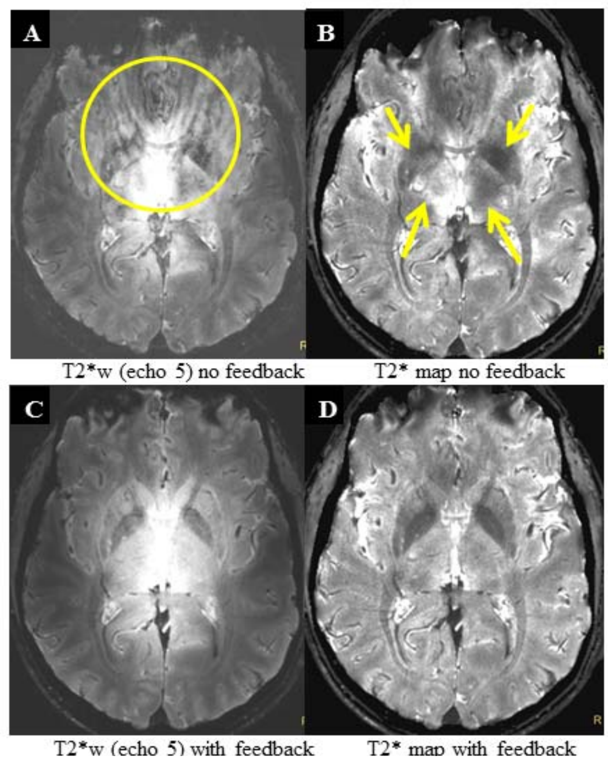

Figure 2: Without feedback ringing like artifacts in the T_2*W image (a) and large intensity variations between corresponding structures (e.g. thalamus left/right) in the T_2* map (b), are apparent. These artifacts are effectively removed when turning on field feedback (c, d).

RESULTS Without field control, breathing-type field fluctuations induced strong artifacts in the phantom data (Fig. 1b), especially at long TE. Feedback control removed these artifacts virtually entirely (Fig. 1c), achieving similar results as in the control experiment (Fig. 1a). The correction propagates to resulting T_2* maps (Fig. 1d-f). Analysis of these maps confirmed a strong decrease in the standard deviation of T_2* estimates from 2.28 ms to 0.48 ms (reference experiment: 0.38ms) by field control, which is also reflected in the box plots (Fig. 3). In the in-vivo experiment, field control likewise strongly reduced breathing artifacts in both the T_2* images and the T_2* maps (Fig 3a-d). The standard deviation of T_2* values over repeated measurements was reduced by 30% on average over the evaluated anatomical regions (Fig 4).

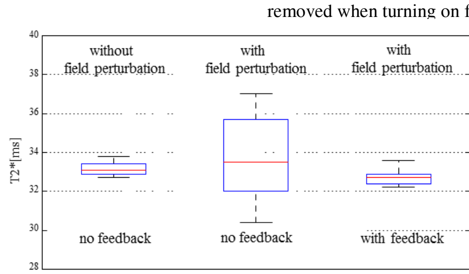

Figure 3: Variation over 10 measurements for liquid 3 *(5.173g $CuSO_4 5H_2O$/L).* Boxplots showing the median (red), 25th and 75th percentiles (blue box), and the whiskers indicates minimum and maximum values.

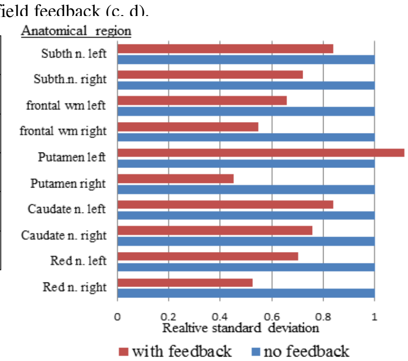

Figure 4: Variation over 5 measurements for different anatomical regions. Feedback field control significantly reduced the standard deviation of T2* values in all but one region of interest.

DISCUSSION/ CONCLUSION The results of this study indicate that real-time higher-order field control significantly improves the accuracy of T_2* mapping in the head at 7T, as shown in phantom experiments and in-vivo. On this basis, it is anticipated that the control approach may be equally beneficial in susceptibility-weighted imaging (SWI) and quantitative susceptibility mapping (QSM). Addressing fields generated by motion of magnetized tissue, the utility of field control is expected to further increase with field strength beyond 7T.

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