7 Tesla Abdominal Imaging using TIAMO

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Introduction

To enhance SNR and certain contrasts such as T2* and BOLD, the B_0 field strength of MRI systems has steadily increased. The resonance frequency rises proportional to the increase in field strength, and therefore the wavelength of the excitation B_1 field is shortened. This makes whole-body and especially abdominal imaging at 7 Tesla and above very challenging due to severe B_1 inhomogeneities [1]. Recently, Time Interleaved Acquisition of Modes (TIAMO) has been proposed as an easy and robust scheme for mitigating these inhomogeneity effects [2]. The basic premise is to excite two (or more) different B_1^+ modes using static RF shimming in an interleaved acquisition, where the complementary RF patterns of the multiple modes can be exploited to improve overall signal homogeneity. The cost in time for acquiring a multitude of images can at least partly be compensated by forming virtual elements in a GRAPPA reconstruction. In this work we present first abdominal images acquired with TIAMO at 7 Tesla.

Materials and Methods

All imaging experiments were performed on a Siemens 7T whole-body system (Magnetom 7T, Siemens Healthcare, Erlangen, Germany) using gradients with a maximum amplitude of 40 mT/m and a maximum slew rate of 200 mT/m/ms. The system is equipped with a custom 8-channel RF shimming system capable of fast switching between different sets of amplitudes and phases and a flexible 8-channel transmit/receive array. Two sets of amplitudes and phases for use in the TIAMO acquisitions were calculated from relative B_1 maps using

$$\mathbf{b}_1, \mathbf{b}_2 = \arg_{\mathbf{b}_1,\mathbf{b}_2} \min \left\{ \left\| \sqrt{(\mathbf{A}\mathbf{b}_1)^2 + (\mathbf{A}\mathbf{b}_2)^2} - \mathbf{m} \right\|^2 \right\}.$$

Here, $\mathbf{b}_1$ and $\mathbf{b}_2$ are complex column vectors with *N* elements containing the shim settings of all *N* channels for the two utilized modes, $\mathbf{A}$ is a matrix with *N* columns containing the B_1^+ values of all voxels in the ROI for all *N* transmit elements, and *m* is a column vector containing the homogeneous target distribution. Please note that the squares and the square root denote element-wise operations.

In the experiments, an entire axial abdominal slice was chosen as the ROI.

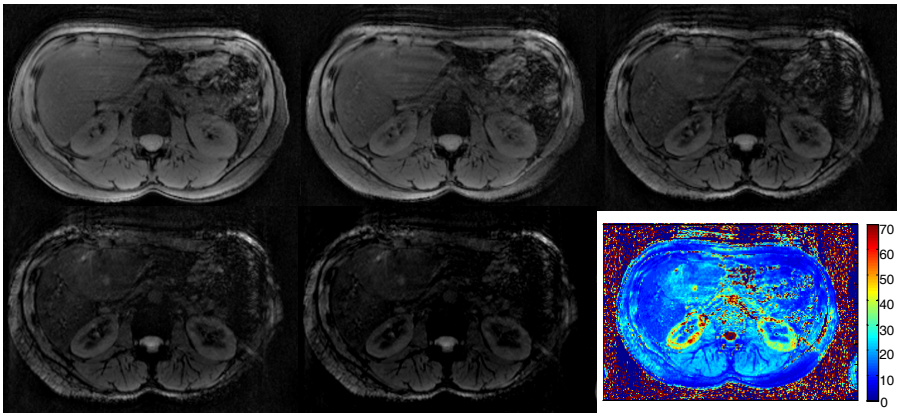

Figure 1: Multi-echo TIAMO gradient echo images with TE = 2.5, 5, 10, 15, 20 ms, showing no B_1^+ artifacts and the resulting T2* map with T2* given in ms.

In this study five healthy volunteers (3 male, 2 female, mean age 24, mean height 1.75 m ± 0.1 m and mean weight 74.6kg ± 10.6 kg) participated. Written informed consent was obtained prior to the examination and the examination was approved by the local ethics committee. All images were acquired during breath hold.

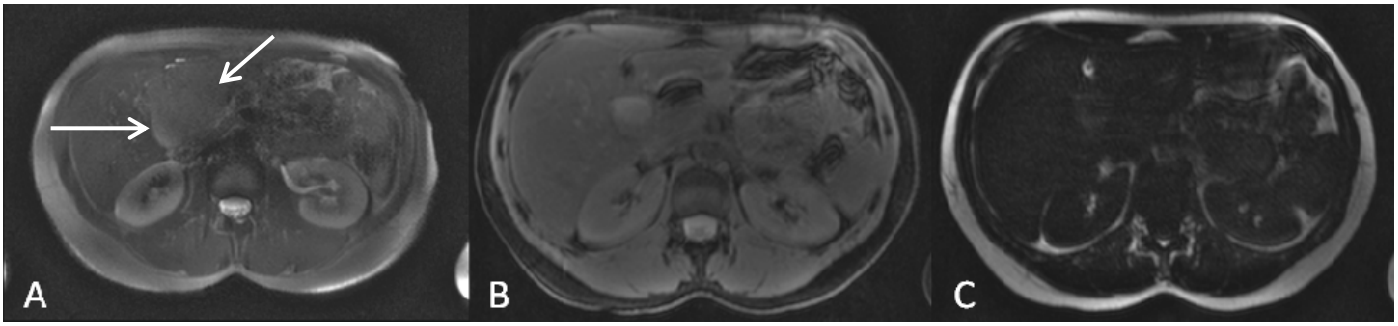

Figure 2: Images of a volunteer with a known focal nodular hyperplasia (arrows). A) HASTE image of the liver/kidney region shows no signal voids with TIAMO. B) Gradient echo image with homogeneous fat suppression. C) Gradient echo image with homogeneous and effective water saturation.

Results and Discussion

Figure 1 shows a set of multi-echo gradient echo images with the resulting T2* map. No signal voids caused by B_1^+ inhomogeneities are visible. Since the T2* contrast is much more pronounced at 7 Tesla than at lower field strengths, it might be of interest in future abdominal studies such as investigations of kidney transplants [3]. Figure 2A shows a spin echo HASTE image at the level of the kidneys and liver. Even though spin echo images are much more affected by B_1^+ inhomogeneities than gradient echo images, the image does not show any signal dropouts. Figure 2B and Figure 2C show gradient echo images with fat saturation and water saturation, respectively. Note that the saturation works well throughout the entire field of view, even though the two individual modes do not have a homogeneous distribution. In the z-direction, the region in which homogeneity is achievable has a dimension of 15 to 20 cm, which is comparable to the coil's field of view.

Conclusion

These early results appear to render promising contrasts and homogeneous images. Abdominal imaging at 7 Tesla seems feasible with TIAMO, since images without signal dropouts can be acquired within a reasonable acquisition time.

References: [1] Vaughan et al., MRM 61 (2009); [2] Orzada et al., MRM 64 (2010); [3] Sadowski et al., MRI 28 (2010)