Initial Results of Abdominal MRI at 7T Using a 16 channel Transmit/Receive Coil

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Introduction

Abdominal imaging examinations constitute a growing fraction of clinical MRI exams. A typical abdominal exam, for example liver screening, comprises (i) T_2-weighted studies with and without fat saturation, (ii) T_1 weighted gradient echo imaging with the fat/water signal in-phase and out-of- phase and (iii) 3D T_1-weighted gradient echo prior to and following administration of contrast media. Since ultrahigh field magnetic resonance imaging becomes more widespread, a range of applications established in the clinical scenario at 1.5 T and 3.0 T is in the research spotlight at 7.0 T - including abdominal imaging - with the ultimate goal to put the intrinsic sensitivity advantage at 7T into clinical use. Arguably, abdominal MRI at 7.0 T earns the moniker of "advanced MR techniques" since some of the inherent advantages of ultrahigh-field MRI are offset by practical constrains associated with RF power deposition limits, dielectric effects and momentary RF non-uniformities. Therefore, transmit-receive (TX/RX) coil array designs are not a nicety but a necessity for ultrahigh field abdominal MR to tackle the challenge of B_1-field inhomogeneities. For all these reasons, this pilot study examines the feasibility of abdominal imaging at 7.0 T using T_1-weighted in-phase and out-of-phase imaging, fat/water imaging and T_2* mapping in conjunction with a 16 channel TX/RX coil array.

Methods

Volunteer experiments were performed on a 7.0 T whole body MR system (Magnetom, Siemens, Erlangen, Germany) together with a dedicated 16-element TX/RX coil array. The coil array consists of a planar superior section and a curved anterior section (Fig. 1). Both sections comprise 8 rectangular elements (2 x 4 array) with an effective size of 13 cm x 6 cm each to provide large volume coverage. High resolution T_1 weighted imaging was perforemd using a GRE technique. Imaging parameters were set to: slice thickness=2.5 mm, nominal flip angle= 38°, acquisition matrix 608 x 1024, FOV=(200 x 330) mm^2, bandwidth= 380Hz/pixel. For in-phase/out-phase TR was set to 730 ms while TE was adjusted to 3.06 ms and 2.55 ms. A multiecho GRE technique was applied for fat/water separation. A multi-shot approach was used to reduce the effective echo spacing by interleaving . For this purpose 8 echoes with an echo spacing of 0.63 ms were used. Water-fat separated image reconstruction used a multi-echo Dixon like technique based on the VARPRO formulation with graphcut optimization [1] to jointly estimate the water, fat. For T_2^* mapping 8 echoes were acquired in-phase with an echo spacing of 1.02 ms. Images were processed with MATLAB (Mathworks, Natick, MA, USA) applying a mono-exponential fitting using nonlinear least squares optimization implemented by Trust-Region algorithm for pixel-by-pixel T_2^* quantification. Shimming was optimized in a rectangular region encompassing the liver.

Results

Fig. 2 illustrates the overall image quality for a central coronal slices using in-phase and out-of-phase gradient echo imaging. The coil arrays sensitivity profile was found to be suitable for a anatomic coverage of 35 cm along the superior-inferior direction. T_1 weighted images delivered high contrast without the need of contrast agent application as demonstrated in Fig.3. It should be noted that significant RF shading occured in deep lying liver regions, although various phase settings were applied for the anterior and posterior sections of the 16 channel TX/RX array. Nonetheless, high details of subtle liver structures can be observed as illustrated by the zoomed image shown in Fig. 4. Besides great vessels, capillaries in the dimension of half a millimeter of diameter were clearly identifiable due to the superb spatial spatial-resolution of (0.3x0.3x2.5) mm^3 which is superior to that commonly achieved in clinical settings at 1.5 T and 3.0 T. Abdominal fat/water imaging at 7T was found to be challenging due to (i) B_0 variations which are more pronounced at 7.0 T vs.lower field strengths, (ii) T_2* dephasing, and (iii) larger chemical shift. Hence, a multishot approach was used to achieve shorter echo spacing. Decreased slice thickness was used to reduce T_2* losses. Fat and water were correctly classified as demonstrated in Fig. 5-7 and good separation was achieved across the full field of view. B_0 uniformity was found to be clinically acceptable as indicated by the T_2* map shown in Figure 8. Using a multi-echo approach T_2* was found to be approximately 7.5±1.8 ms for the parenchyma and approximately 20 ± 2.3 ms for the large liver vessels.

Discussion and Conclusions

Despite the observed non-uniformities of the RF field distribution, our initial results suggest that high spatial resolution anatomic details accomplished at 7.0 T can be considered to be beneficial in clinical liver imaging. As transmit array hardware becomes more readily available, 7.0 T MRI may be expected to transition into an enabling technique for abdominal imaging. However, further clinical studies have to be conducted to validate the diagnostic capability of 7T liver imaging versus established abdominal imaging protocols used in day-to-day clinical routine at 1.5T or 3.0 T. This requires further image quality improvements by using patient tailored B_1^+ shimming. Admittedly, achieving this goal asks for further developments in the areas of B_1 mapping and B_1 shimming tailored to each patient's size and geometry.

Fig. 1 Posterior and anterior sections of the 16 channel TX/RX array placed on a mannequin.

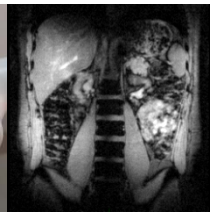

Fig. 2: T_1 weighted coronal images of a central abdominal slice derived from in-phase (left) and out-of-phase gradient echo imaging. using a voxel size of (0.4x0.4x2.5) mm^3.

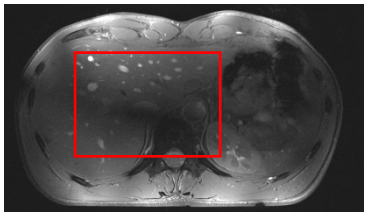

Fig. 3: T_1 weighted axial slice acros the liver derived from gradient echo imaging using a spatial resolution of (0.3x0.3x2.5) mm^3. No contrast agent was applied.

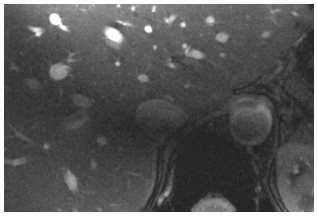

Fig. 4: Zoomed view of the region marked in red in Fig.3. Subtle anatomic liver structures are clearly identifiable including capillaries in the dimension a diameter of 0.5mm.

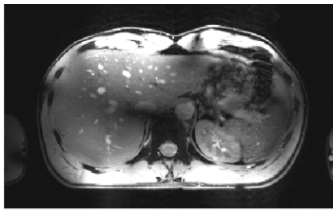

Fig. 5: Abdominal Water image for a normal volunteer acquired at 7T.

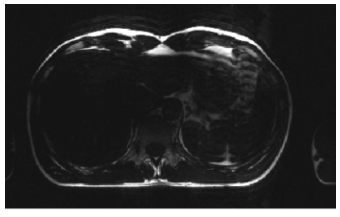

Fig. 6: Abdominal fat image for a normal volunteer acquired at 7T.

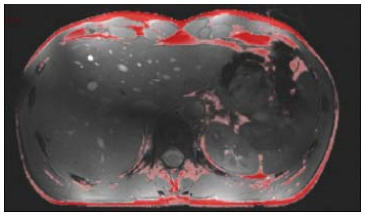

Fig.7: Fat (red) plus water (grey) image of a healthy subject acquired at 7T.

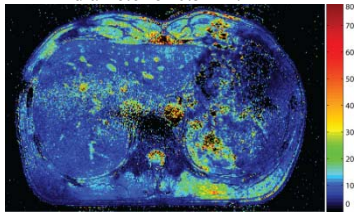

Fig. 8: Abdominal T_2* map showing a rather uniform T_2* distribution in the liver.

References:[1] Hernando D, et al. MRM. 2010 Jan; 63(1):79–90.