Introduction
Abdominal imaging examinations constitute a growing fraction of clinical MRI exams. A typical abdominal exam, for example liver screening, comprises (i) T₂-weighted studies with and without fat saturation, (ii) T₁ weighted gradient echo imaging with the fat/water signal in-phase and out-of-phase and (iii) 3D T₁-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 B₁-field inhomogeneities. For all these reasons, this pilot study examines the feasibility of abdominal imaging at 7.0 T using T₁-weighted in-phase and out-of-phase imaging, fat/water imaging and T₂* 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 T₁ weighted imaging was performed 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) mm², bandwidth=380 Hz/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 multislice 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. The image quality was found to be approximately 7.5±1.8 ms for the parenchyma and approximately ±2.3 ms for the large liver vessels. Therefore, transmit-receive coil array designs are not a nicety but a necessity for ultrahigh field abdominal MR to tackle the challenge of B₁-field inhomogeneities. For all these reasons, this pilot study examines the feasibility of abdominal imaging at 7.0 T using T₁-weighted in-phase and out-of-phase imaging, fat/water imaging and T₂* mapping in conjunction with a 16 channel TX/RX coil array.

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 anatomic coverage of 35 cm along the superior-inferior direction. T₁ weighted images delivered high contrast without the need of contrast agent application as demonstrated in Fig. 5. It should be noted that significant RF shading occurred 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 super spatial-resolution of (0.3x0.3x2.5) mm³ 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) B₀ variations which are more pronounced at 7.0 T vs lower field strengths, (ii) T₂* dephasing, and (iii) larger chemical shift. Hence, a multi-shot approach was used to achieve shorter echo spacing. Decreased slice thickness was used to reduce T₂* losses. Fat and water were correctly classified as demonstrated in Fig. 5-7 and good separation was achieved across the full field of view. B₀ uniformity was found to be clinically acceptable as indicated by the T₂* map shown in Figure 8. Using a multi-echo approach T₂* was found to be approximately 7.5±1.8 ms for the parenchyma and approximately ±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 B₀ shimming. Admittedly, achieving this goal asks for further developments in the areas of B₁ mapping and B₀ shimming tailored to each patient’s size and geometry.

Fig. 1: Posterior sections of the 16 channel TX/RX array placed on a mannequin.
Fig. 2: T₁ 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) mm³.
Fig. 3: T₁ weighted axial slice across the liver derived from gradient echo imaging using a spatial resolution of (0.3x0.3x2.5) mm³. 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.