Clinical liver MRI at 3.0 Tesla using parallel RF transmission with patient-adaptive B1 shimming

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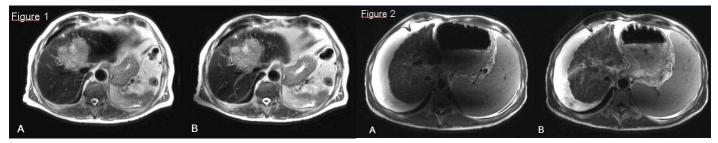
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Introduction: The clinical implementation of high field MRI systems has introduced new challenges for body imaging with respect to B1 field non-uniformities, which can result in the generation of standing waves and signal loss particularly in abdominal imaging. Several approaches have been proposed to achieve a more homogeneous excitation and to avoid a degradation of image quality at higher magnetic fields, e.g. the use of RF cushions [1-2]. The recent development of parallel RF transmission techniques allows for independent adjustment of RF transmission signals enabling the concept of RF shimming [3-7]. In this study multi-source RF transmission with patient-adaptive RF shimming was evaluated for MR imaging of the liver at 3.0 Tesla.

Methods: 22 patients (mean age 52.7±15.2) suspected of having focal or diffuse liver disease on the basis of ultrasonographic and/or laboratory findings underwent a standardized MR sequence protocol including axial and coronal T2w TSE, axial T1w FFE in- and opposed phase, axial DWI and a 3D-GRE dynamic acquisition after contrast media injection. For all exams, a clinical 3.0T MRI system (Philips Achieva 3.0T TX) equipped with fully flexible multi-source RF transmission (MultiTransmit) was used. The RF power was distributed to the ports of the system body coil using multiple independent RF transmit channels under full software control. With this design it is possible to independently control phase, amplitude and shape of the RF waveforms. For each patient a B1-map was acquired for calibration. Depending on B1-homogeneity the RF channels were controlled to compensate inhomogeneities. To determine the effect of patient-adaptive B1-shimming on homogeneity and dielectric artifacts, the following MR sequences were evaluated using single transmit and MultiTransmit with RF shimming: axial T2w TSE (22/22), axial T1w FFE in- and opposed phase (10/22), DWI (12/22). Images were analyzed independently by two radiologists regarding overall image quality on a 5-point evaluation scale: (5) excellent, uniform contrast over entire FOV, no standing wave artifacts, (4) good, mild standing wave artifacts, no impairment of image interpretation, (3) moderate, standing wave artifacts interfering with image interpretation, (2) poor, prominent standing wave artifacts, diagnostic quality questionable, (1) non-diagnostic. In addition, readers were asked to rate lesion conspicuity [good(3), moderate(2) or poor(1)] for T2- and diffusion-weighted images. P-values were calculated using the non-parametric marginal homogeneity test. Interobserver agreement was calculated using Cohen´s kappa.

Results: Both readers independently considered the quality of T2w TSE and DWI acquired with MultiTransmit after patient-adaptive RF shimming as significantly better as compared to single transmit. Mean image quality of T2w TSE sequences was rated by reader 1 (reader 2) to improve from 3.09±0.61 to 4.23±0.43 (3.09±0.53 to 4.18±0.39) [both $p<0.0001$] using patient-adaptive RF shimming. Lesion conspicuity for T2w TSE improved from 2.18±0.59 to 2.95±0.21 (2.27±0.63 to 2.95±0.21) [both $p<0.0001$]. For DWI image quality was rated to improve from 3.25±0.75 to 4.08±0.51 (3.45±0.52 to 4.18±0.60) [both $p<0.05$], while lesion conspicuity improved from from 2.27±0.79 to 2.91±0.30 (2.45±0.52 to 2.91±0.30) [both $p<0.05$]. Image quality of in- and opposed-phase T1w FFE was rated to improve from 4.20±0.63 to 4.50±0.53 (4.20±0.63 to 4.50±0.53) [both not significant]. In the majority of cases there were no visual differences in image quality of T1w FFE sequences with or without MultiTransmit. However in 3 patients (2 with ascites) image quality was rated superior with MultiTransmit and patient-adaptive RF shimming compared to single transmit. Quality improvement was most prominent in the left liver lobe, the peripancreatic and paravertebral region and in the posterior parts of the right liver lobe. Interobserver agreement was almost perfect ($\kappa>0.8$ in all cases).

Conclusion: Parallel RF transmission with patient-adaptive RF shimming significantly improves image quality for liver imaging at 3.0 Tesla by reducing or eliminating B1-inhomogeneity artifacts.

Figure 1: 76 y/o patient with metastasized GIST. **[A] T2w TSE without parallel RF transmission. Standing wave artifacts interfere with delineation of left liver lobe anatomic structures [B] T2w TSE with parallel RF transmission and patient-adaptive RF shimming. Anatomic structures of left liver lobe are clearly depicted. Figure 2: 40 y/o patient with liver cirrhosis and ascites. [A] T2w TSE without parallel RF transmission. Severe standing wave artifacts impairing image interpretation. [B] T2w TSE with parallel RF transmission and patient-adaptive RF shimming resulting in improved image quality (rated as 4 by both readers).**

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