Clinical evaluation of high permittivity pads for improving abdominal image quality at 3T

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Target Audience: Clinicians and basic scientists interested in abdominal imaging at 3T.

Purpose: To assess the clinical potential of recently developed high permittivity pads [1] in improving image quality for abdominal imaging of patients using a dual-transmit 3T MRI system.

Introduction: Migration of abdominal imaging protocols from 1.5T to 3T has been hampered by image artifacts at 3T. The fundamental reason are spatial inhomogeneities in the transmit RF field. The problem is sufficiently important that "dual-transmit" 3T MRI systems have been developed and explored for amelioration of these effects [2], which have helped but not eliminated the problem. Multiple channel transmit systems are actively being investigated, but are likely to be extremely expensive and moreover will not solve the problem in the thousands of already installed 3T systems around the world. A second approach to address the issues of RF inhomogeneity in 3 Tesla abdominal imaging is the use of "dielectric pads." However, many initial studies of this approach utilized pads simply made from ultrasound gel with dissolved paramagnetics such as manganese chloride to give a short T_2 and hence low background signal. The pads are large and cumbersome and have yielded mixed results, and thus have not found widespread use. However, recently, pads made from high permittivity materials such as barium titanate have been developed and shown by simulation and experiment to improve image uniformity in abdominal imaging [1, 3]. Here, we show initial clinical evaluation of these pads in patients undergoing routine clinical liver MRI in dual transmit systems.

Methods: Barium titanate based pads with a measured relative permittivity of ~300 were produced based as described previously [3]. This prospective study was HIPAA and local IRB compliant. Ten patients (4 females, 6 males; mean age 52.1, range 33-78 years) were prospectively recruited. Dual-transmit Siemens Magnetom Verio 3T scanners with 12 channel body arrays were used to acquire fat suppressed 3D VIBE images (TR/ TE/ α 3.5/1.3/9, voxel size 1.8×1.2×2 mm, acquisition bandwidth 539 Hz/ pixel), without and with two pads (1 cm thick, dimensions 28 x 22 cm (L-R x H-F) placed over the anterior abdominal wall. The VIBE sequence was chosen because it is critically important in abdominal lesion characterization. The images were anonymized and loaded onto a Picture Archive and Communication System (PACS) station and displayed side by side, randomized right versus left. Two board-certified body-imaging radiologists (R1, R2) reviewed the cases for image homogeneity. Each reviewer assigned a score on a 5-point Likert scale describing the degree of magnetic field inhomogeneity: 4- no visible inhomogeneity, 3- mild inhomogeneity not affecting diagnostic image quality, 2- moderate inhomogeneity mildly reducing diagnostic image quality, 1- severe inhomogeneity severely reducing diagnostic image quality, and 0- profound inhomogeneity with no diagnostic image quality. Subsequently, a two alternative forced choice test was conducted, where each reviewer selected scan sequences with better field homogeneity out of each pair of image sets obtained with and without pads in place. The reviewer also quantified the difference of inhomogeneity as subtle, moderate or large. Comparison of the degree of inhomogeneity was performed using the Friedman and paired t-tests. P-values less than 0.05 were considered to be significant.

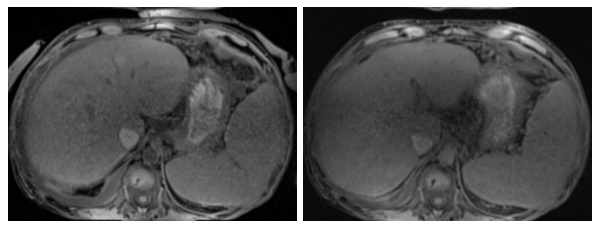

Fig 1: Images with and without pads (left and right) of a subject where both readers preferred the sequence obtained with pads. Note increased homogeneity centrally in the image on the left.

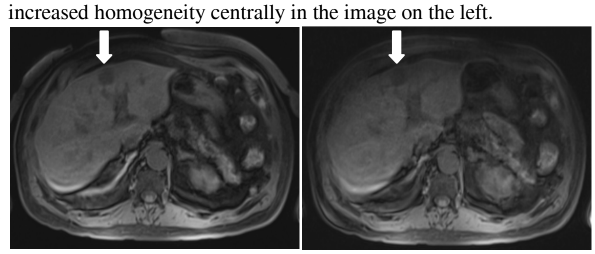

Fig 2: Images with and without pads (left and right) of another subject where both readers preferred the sequence obtained with pads. Image quality with pads is particularly superior over the anterior abdomen, in the vicinity of a lesion (arrows).

Results: Differences in inhomogeneity median scores between reviewers and use of high permittivity pads was near significance as measured by the Friedman test ($F=2.9$; $p=0.05$). Mean value (±standard deviation) of rating scores of images with and without pads for R1 were 2.9±0.3 and 2.5±0.5, respectively. Corresponding values for R2 were 2.9±0.5 and 2.6±0.7. Results of the paired t-test for R1 were statistically significantly different ($p=0.03$) but were not significantly different for R2 ($p=0.08$) when degree of inhomogeneity (no pads vs. pads) was compared. Reviewer 1 preferred images with pads in 4 cases, images without pads in 2 cases with no preference in remaining 4 cases. Reviewer 2 preferred images with pads in 3 cases, images without pads in no cases and no preference in remaining 7 cases. Two representative cases where the images with pads were preferred to those without pads are shown in Figures 1 and 2.

Discussion: Our results demonstrate a strong trend towards better field homogeneity in images obtained using dielectric pads, with the pooled data from the two reviewers showing an improvement at $p=0.05$ and significant improvement for Reviewer 1. Reviewer 2 also trended towards significant perceived improved image homogeneity. While a larger subject population is needed for a more definitive evaluation, these results are extremely encouraging, given that better image quality can be obtained at 3T without expensive hardware modifications. The implication of the gain in image quality on patient care is particularly well illustrated in Figure 2, where lesion conspicuity is improved in a region where there is signal inhomogeneity without the pads. Larger scale studies are needed to verify these early results. Further work is also necessary to explore the differential effects of the pads on patients with varying body habitus, and to study different pad geometries and positioning.

Conclusion: An initial pilot study has shown that a pad made from specialized high permittivity material increases the image quality of abdominal scans on a dual-transmit 3T MRI system.

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References: [1] Haines K et al., *J.Magn.Reson,* 2010;203:323-327. [2] Willnek WA et al., *Radiology* 2010;256(3):966-975. [3] de Heer P, et al., *Magn Reson Med*, 2012;68:1317-24.