Abdominal MRI at 3.0T: Parallel Radiofrequency Transmission (MTX) Improves the Signal-to-Noise and Contrast-to-Noise Ratios and Body-habitus-dependent B1 Inhomogeneity

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Introduction Compared to 1.5T, 3.0T MRI can provide higher signal to noise ratio (SNR), which can be used to increase the image resolution, shorten the image acquisition times, improve the quality of MR spectroscopy, and allow for increased parallel imaging acceleration factors[1]. Unfortunately, abdominal MR imaging at 3.0T can also suffer from a number of challenges such as radiofrequency (RF) inhomogeneity, increased specific absorption rate (SAR), and greater susceptibility effect[1]. in particular, various combinations of the incident, reflected, and standing waves give rise to RF field inhomogeneities at 3.0T[2]. RF eddy currents also create an additional B1 field and the resultant image artifacts are induced by the B1 of the coil and their effects are dependent on the conductivity and permittivity of the tissues[2]. With high conductivity B1 cancellation occurs and areas of signal loss or "dark spots" are created. Other factors contributing to the artifacts at 3.0T include the patient's body habitus and the presence of ascites. The purpose of our study was to determine if the application of parallel RF transmission (MTX) at 3.0T improves the signal-to-noise (SNR) and contrast-to-noise (CNR) ratios for liver MRI, and if this correlates with body habitus.

Materials and Methods A retrospective analysis included 224 consecutive patients who underwent 3.0T abdominal MRI studies between 3/10/10 through 7/21/10. Seventeen patients were excluded from our study based on the defined inclusion and exclusion criteria. The final study population (n=207) consisted of 112 females and 95 males (mean age 55, range 17-86 years). All subjects were imaged with a 3.0T MRI system (Achieva TX, Philips Healthcare, Best, The Netherlands) using a comprehensive liver MRI protocol with multiple imaging sequences. From this protocol, the Single-shot Turbo Spin-echo (SSTSE) respiratory-triggered sequence was chosen to assess the signal-to-noise and contrast-to-noise ratios. Identical SSTSE acquisitions with TR ∞, TE 120 msec, voxel resolution of 1.0x1.0x5.0 mm, and typical acquisition times of approximately 1:30 minutes depending upon respiration rate of each patient, were acquired first with traditional circularly polarized RF transmission followed by MTX. The SSTSE was chosen intuitively for this study due to the well-known phenomenon that the large number of RF refocusing pulses applied would accentuate any RF inhomogeneities via increased tissue shading within the resultant images. Signal intensity and standard deviation were measured using anatomically identical regions of interest (ROI), 100mm^2 in size, by carefully placing in the ROIs in the darkest area caused by B1 inhomogeneities in the left lobe of the liver at two different anatomical levels and at one level in the right liver. In each patient, the ROIs were placed first in images without MTX containing the dark areas, and then in images with MTX. The ROIs on the images with MTX were placed at similar anatomic levels and location as those placed on the images without MTX. Reference ROIs were placed in the spleen to calculate the contrast-to-noise (CNR) between the liver and the spleen, which is often an indication of liver-to-lesion contrast. Mean SNR and CNR without MTX and with MTX were compared using a 2-tailed t-test with $p<0.05$ attaining statistical significance. To assess the relationship between the body habitus and the SNR and CNR, we calculated the elliptical cross sectional body area for all subjects based on the measured transverse and anterior-posterior measurements of the widest portion of each patient's abdomen and normalized the areas relative to the largest calculated patient cross sectional body area. These ordered cross-sectional body area values were plotted against the difference between the SNR and CNR values obtained with and without the application of MTX, and a linear regression line was then fit to the data. Analysis of variance (ANOVA) was performed comparing the normalized cross-sectional body area with the difference in SNR and CNR values with and without the application of MTX.

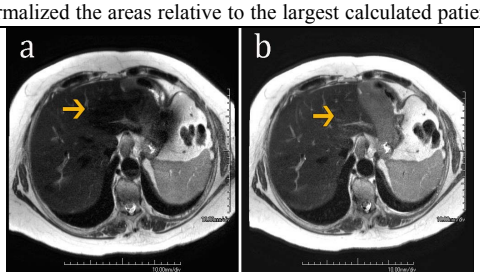

Figure 1: (a) Obese patient without MTX, superior left liver lobe, and (b) with MTX showing significant improvements.

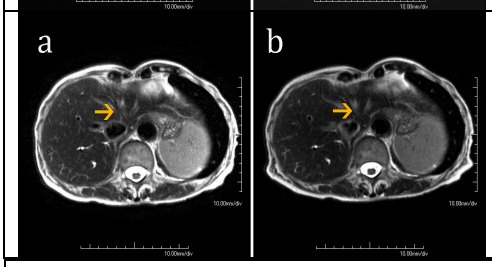

Figure 2: (a) Slim patient without MTX, superior left liver lobe, and (b) with MTX demonstrating minimal improvements.

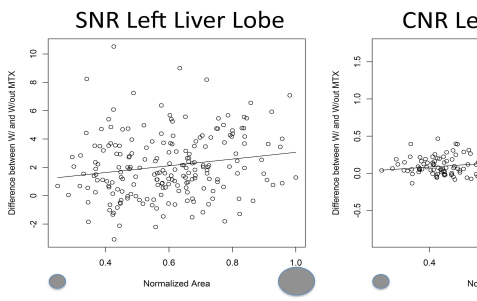

Fig. 3: Linear regression plots showing the difference between the SNR and CNR with and without MTX in the left liver versus the normalized abdominal cross-sectional area.

Results Figures 1 and 2 show typical SSTSE images without and with MTX for obese and slim patients, and the associated tissue shading (arrows). Mean values for SNR and CNR without the application of MTX were 4.35 and 0.3 respectively, while mean SNR and CNR with MTX were 6.34 and 0.43 respectively. This difference was found to be statistically significant ($p< 0.001$). Similar results were obtained at the additional axial level in the left lobe of the liver, while non-significant results, $p>0.05$, were observed in the right lobe of the liver. Linear regression model analysis demonstrated significant improvements in SNR and CNR as body dimensions increased, with p-values of 0.0112 and 0.0066 respectively in the superior portion of the left liver (Figure 3). Similar improvements were observed at the additional level in the left lobe of the liver. The right liver lobe did not show significant improvements (p=0.201 for SNR, and p=0.918 for CNR). Additionally, ANOVA results revealed similar significant results, with a greater improvement in SNR or CNR when compared to the normalized body area values with the application MTX than without its application in the measurements taken in the left lobe of the liver, and non-significant results for the right lobe of the liver.

Discussion and Conclusion Abdominal imaging at 3.0T has been considered substandard due to dielectric effects, standing wave artifact and B1 inhomogeneities[3]. The results of our study clearly demonstrate that the application of MTX in single-shot turbo spin-echo sequences significantly improves SNR and CNR within the liver. Additionally, our study shows that the improvements are unequivocally related to the body habitus of the patients, with the greatest improvement in SNR and CNR occurring in larger patients. The most likely mechanism underlying this improvement is that the application of MTX at 3.0T corrects the B1 field inhomogeneities, as has been demonstrated previously[3]. Our results are clinically significant because the application of MTX corrects the dark areas created by B1 inhomogeneities resulting in improved lesion detection most pronounced in the left liver. Our study shows that MTX can be applied to all patients yielding more predictable results than previous methods. The SSTSE sequence was used as a model, which is one of the most SAR and B1 homogeneity intensive sequences. These improvements might translate well with other sequences that are less SAR intensive, but are influenced by inhomogeneous B1 fields. In conclusion, the application of MTX at 3.0T significantly improves the SNR and CNR of the liver. The improvement is most pronounced in individuals with the largest body habitus. Improved B1 uniformity can result in lower local SAR which can improve the duty cycle of most sequences, leading to overall more time efficient sequences and exams at 3.0T.

References: [1]K.J. Chang, I.R. Kamel. Appl. Radiol. 39:22-31 (2010), [2]G. Glover, C. Hayes, N. Pelc, et al. J. Magn. Reson. (1969). 64:255-70 (1985), [3]W.A. Willinek, J. Gieseke, G.M. Kukuk, et al. Radiology 256:966-975 (2010).