Accelerating CEST-MRI for 3D renal imaging

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INTRODUCTION:

CEST-MRI is gaining recognition as a valuable tool for characterization of tumors and other ailments. However, its application in body imaging is still relatively limited. Specifically, applications to renal imaging are hampered by fat artifacts, motion, and limited coverage. Here we are addressing three of the challenges: fat-free, fast volumetric acquisition that also allows for a motion insensitive protocol. We implement a 3D multi point Dixon acquisition, utilizing Compressed SENSE (CS) acceleration and comparing different k-space trajectories: (i) low-high cartesian, (ii) Contrast Enhanced Timing Robust Acquisition[1,2] (CENTRA), (iii) Cartesian Acquisition with Spiral Profile Reordering[3] (CASPR). All methods are implemented under timed breathing and employ post processing Structuralized Normalized Mutual Information[4] motion correction (SNMI). The results are compared in terms of image quality and 3D coverage.

METHODS:

3T MRI (Ingenia, Philips Healthcare) equipped with dual transmit body coil for transmit and 28-channel abdominal array for receive was utilized for the study. For image acquisition, a 3D TFE single shot multi-point Dixon acquisition[5] sequences were implemented. For CEST saturation we used: 40x50 msec pulses, for a total saturation length of 2 sec, enabled by alternated parallel transmission, B_{1rms}=1.17 μT, and 15 points in the Z-spectrum [±7 ppm] or [±10 ppm]. Other acquisition parameters were FOV=360x300 mm, voxel size 3x3 mm^2, slice thickness = 5mm, number of slices varied from 3 to 9. Single shot acquisition included 3 echo Dixon with TR/TE1/DTE = 3.4/1.04/0.6 msec. Acquisition length varied depending on the acquisition scheme, the TFE length was adjusted to be minimum number accommodating the whole 3D acquisition for a given scheme and acceleration. The CEST processing was done on the pixel-by-pixel basis using custom Matlab codes. The processing utilized water-only images, followed by motion correction using SNMI registration, B_0 correction using minimum of Z-spectra and standard MTR_{asym} calculation.

RESULTS:

Using the timed breathing scheme, along with auditory coaching from the scanning technologist, allowed for comfortable breathing patterns that were well tolerated. Single shot 3D centric acquisition with CS allows acquisition of up to 5 slices within 6 to 7 sec breathing pattern. However, single shot acquisition of non-accelerated 3D leads to prohibitively long acquisition time and loss of CEST saturation. This is illustrated in Figure 1. Here, CS=1, 2 and 3 led to single shot factors/TFE shot acquisition time of 525/1,783 msec, 240/815 msec, 120/408 msec. The CEST contrast loss occurs due to T_1 influence and Z-magnetization recovery during acquisition. Using CS allowed for significant reduction of the acquisition train lengths such that the loss of CEST effect was not significant. From the three k-space patterns tested, the best results were produced using CS-CASPR trajectory (Figure 2). CASPR allowed acquisition of 9 slices in the single shot with shot length 224/759 msec.

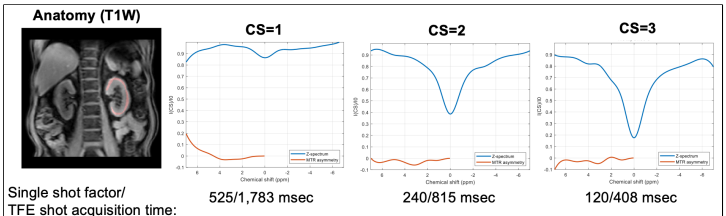

Figure 1. Influence of the CS factor/3D shot acquisition time

DISCUSSION:

3D CS-CASPR readout resulted in the maximum number of slices, 9, covering 4.5 cm of kidney. Thus, the whole kidney coverage within a single shot is feasible. While the 3D CASPR readout adds to a motion-insensitive acquisition of any of the single RF-offset frames of the Z-spectrum, there was still a need to correct through-frame motion artifacts by post-processing image alignment. Advanced processing (e.g. multi-Lorentzain fit, AI denoising, 3D registration) might further improve the results

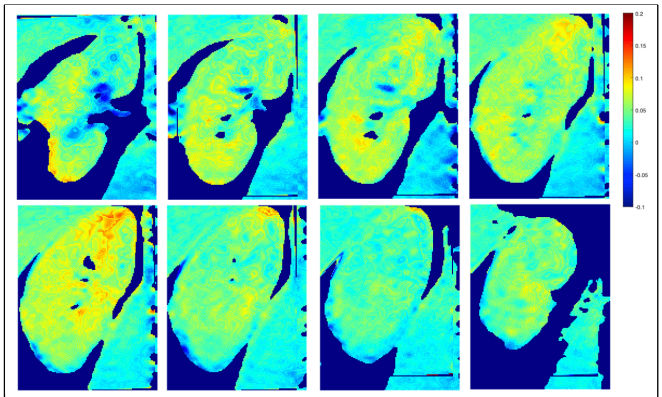

Figure 2. Typical MTR_{asym}(1ppm) map of a kidney in a healthy volunteer. First slide (kidney edge) is not shown.

CONCLUSION:

Acceleration is necessary to achieve 3D kidney CEST-MRI. CS using advanced motion-insensitive k-space trajectory (CASPR) allows for whole-kidney CEST imaging, that comfortably fits with the breathing pattern in normal volunteers. Evaluation of this technique in kidney cancer patients is forthcoming.

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