Multi-Echo Tricks Acquisition (META): a high spatio-temporal resolution multi-point Dixon sequence for dynamic contrast enhanced MRI

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Introduction: Dynamic contrast enhanced MRI (DCEMRI) is widely used in clinical abdominal and pelvic MRI for tissue characterization and visualization of focal lesions. The technique affords adequate spatial resolution but temporal resolution is often insufficient for visualizing hypervascular tumors such as neuro-endocrine metastases and hepato-cellular carcinoma (HCC). Optimal timing of contrast arrival in the organ of interest is critical in capturing "arterial" phases and improving lesion conspicuity. Furthermore, traditional fat suppression methods perform suboptimally at 3T due to B_o and B_1 inhomogeneities, causing non-uniform fat suppression across the image. We report a new DCEMRI technique called META (Multi-Echo Tricks Acquisition) that combines a multi-echo TRICKS [1] scan with a two-point Dixon fat-water reconstruction algorithm [2] to generate fat-only and water-only images at very high spatio-temporal resolution.

Methods: Pulse sequence- A dual echo bipolar readout 3D SPGR pulse sequence with a TRICKS k-space interpolation scheme [1] was developed. Elliptical k_y-k_z space was divided into 4 equal annuli (A-D) and the acquisition schedule ABACADAB… with 5/9 typical reconstructed phases for pelvic/abdominal imaging. For abdominal scans, each set of 4 consecutive regions constituted a breath-hold while pelvic exams were acquired free-breathing. Linear interpolation was performed in k-space to generate a full k-space dual echo slab at each temporal point (i.e. at each A,B,C and D) followed by an online two-point Dixon image reconstruction with a phase correction algorithm as described in [2].

Experiments- Imaging parameters for META were as follows- 15° flip, $\pm$ 167 kHz bandwidth, TR/TE$_1$/TE$_2$ 4-6/1.2/2.4 ms, 256x192 matrix, 26-35 cm FOV, 3-4 mm thick, 48-60 slices, scan time for each set of 4 consecutive regions (breath-held for abdominal imaging) was approximately 20s, effective temporal resolution 5s. For comparison, a conventional fat suppressed 3D SPGR sequence (LAVA) was acquired with the same spatial resolution and similar acquisition parameters except BW was 83 kHz and TR/TE 3.5-4/1.2 ms. All breath-holds including scout scans were at end-expiratory to maintain k-space consistency for the TRICKS scheme. After obtaining informed consent, 10 patients, referred for MRI of hepatic metastases, renal masses, polycystic disease or perianal fistulae were imaged on a GE 3T Excite system (GE Healthcare, Waukesha, WI) using an 8-channel torso array coil using both META and LAVA. The images were evaluated for quality of fat suppression, SNR, artifacts and preference by two radiologists.

Results: Figure 1 compares axial sections from a conventional fat suppressed 3D SPGR scan (a) and a water-only reconstruction from the proposed META sequence (b). Note the improved contrast, structural conspicuity and the uniformity of fat suppression using META (b). Figure 2 shows six phases (a-f) out of 10 reconstructed phases from a META scan after contrast injection on a patient with a suspected renal mass and a cyst. Conventional pre- and post-contrast LAVA images are shown in (g-j). The progressing enhancement of the kidneys in the arterial phase can clearly be seen in the high temporal resolution META scans. Figure 3 shows four phases of a META scan on a patient with polycystic liver disease. Note that the multi-phasic acquisition has captured the aortic-hepatic arterial (b), portal venous (c) and the hepatic venous enhancement (d). The quality and degree of fat suppression and SNR were significantly better in the META scans compared to conventional LAVA ($p < 0.05$). For overall image quality, the META scans scored qualitatively better than conventional LAVA scans and was the more preferred sequence.

Conclusion: The proposed META sequence, a combination of TRICKS and a 2-point Dixon-based fat-water separation method provided excellent fat suppression on a 3T scanner where conventional fat saturation techniques are often suboptimal. META also generated high temporal resolution multi-phasic images to allow visualization of structures with rapid contrast enhancement and washout. The use of elliptical centric TRICKS obviates the need for a timing bolus and offers modest immunity to motion artifacts that may occur due to respiratory motion near the end of the breath-hold period. This method could also generate in-phase and opposed-phase images along with the water and fat images for the pre-contrast phase, obviating the two additional SPGR acquisitions that are typically acquired, further reducing the overall exam time.

References:
[1] Korosec et al. MRM. 36:345-51 (1996). [2] Ma et al. MRM. 52:415-419 (2004). [3] Saranathan et al. ISMRM 2006, p2207.
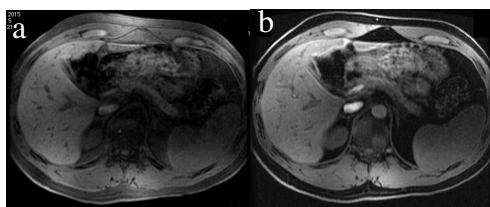
Figure 1. Comparison of a fat suppressed 3D SPGR scan (a) with a "water-only" reconstruction from the proposed META sequence (b).
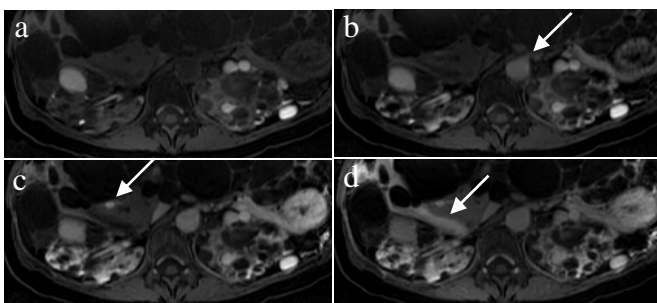

Figure 3. Four phases (out of 10) from a patient with polycystic liver and kidney disease- pre contrast (a), phase 1 (b), phase 3 (c) and phase 6 (d) from a META 3D acquisition clearly depicting multiphasic enhancement (arrows) of the aorta/hepatic artery (b), portal vein (c) and hepatic vein (d). Note also the image contrast and uniformity of fat suppression.
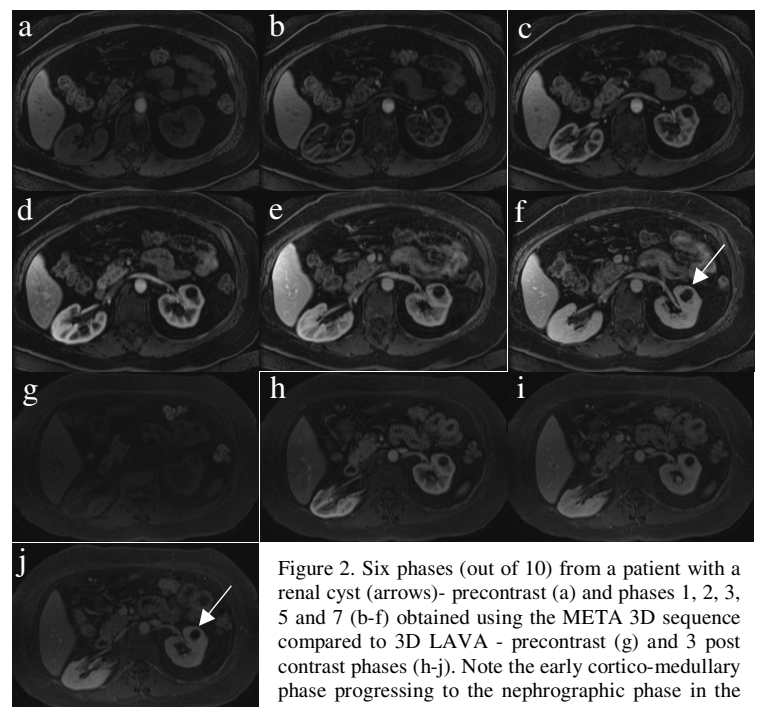

Figure 2. Six phases (out of 10) from a patient with a renal cyst (arrows)- precontrast (a) and phases 1, 2, 3, 5 and 7 (b-f) obtained using the META 3D sequence compared to 3D LAVA - precontrast (g) and 3 post contrast phases (h-j). Note the early cortico-medullary phase progressing to the nephrographic phase in the kidneys (images b-d) as well as the image quality.