# Initial experience using Magnetization Transfer with Iterative Decomposition of water and fat with Echo Asymmetry and Least-squares estimation (MT-IDEAL) in the abdomen.

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**Introduction:** Magnetization transfer (MT) imaging has been used successfully to study the macromolecular components in a variety of tissues [1], providing contrast in several clinical conditions [2]. However, to date, clinical MT imaging within the abdomen has failed to deliver significant contrast and has proven to lack sensitivity to detect liver fibrosis [3]. This failure is potentially due to the difficulty in removing the confounding effect of lipid infiltration, which happens in combination with the changes in the macromolecular content in liver fibrosis.

As lipids are known to have no MT effect [4], their presence in a voxel masks macromolecular MT changes. This work, developed from that first reported in muscle [5], aims to remove the MT dependence on lipid concentration through integration of IDEAL fat/water separation [6]. This new method, MT-IDEAL, uses multiple gradient echoes to increase the SNR as well as calculate the fat fraction, $T_2^*$, and an MT ratio (MTR) map that is unbiased by the presence of fat. It is hoped that this will eventually allow for investigation of pathological changes in fat content and fibrosis within intra-abdominal organs in a wide range of diseases using a single imaging technique.

**Purpose:** This study was performed to: 1) assess the feasibility of MT-IDEAL imaging in the abdomen using commercially available MR hardware and sequences; 2) compare resultant MTR values calculated using standard MT methodology and using MT-IDEAL optimized pulse sequences in several intra-abdominal organs using a sample of healthy volunteers (for later comparison to subjects with intra-abdominal pathologies).

**Methods:** The previously reported IDEAL methodology with and without an off-resonance MT pulse was applied where the resultant signal intensities in a given voxel are modeled using the complex fat and water ($MT_{on}$ and $MT_{off}$) signals [5]. Local field off-resonance effects were taken into account using the apparent transverse relaxation rate. Calculation of the solution to the set of coupled equations using the IDEAL reconstruction [6] was performed offline in MATLAB (MathWorks, Inc., Natwick, USA) with the resultant water isolated MTR maps calculated (see Figure 1). Standard MTR values were calculated as has been previously reported using pulsed MT imaging [7].

All data were collected at 3 T using a wide-bore Magnetom Verio system (Siemens Healthcare, Germany) with Gaussian shaped MT pulses applied using the body transmit coil (offset frequency =1950 Hz, bandwidth = 375 Hz, duration = 9984 μs, 500 degree flip angle). Body matrix and spine coil elements were used for receive (Siemens Healthcare, Germany). For MT-IDEAL optimized sequences N = 14 unique echoes ranging from 2.71 ms to 22.31 ms (approx. effective echo spacing of 1.51 ms) were collected over two acquisitions, one with and one without an MT pulse. A conventional MT dataset was also collected using the product sequence with a 2.71 ms echo-time. Both the conventional MT and MT-IDEAL image data sets were acquired during a single breath-hold (<16 s). Imaging was performed using a standard 2D gradient echo sequence with TR = 60 ms, slice thickness = 10 mm, in-plane resolution 350 × 328.3 $mm^2$. Nonsensical values in resultant MTR maps for both datasets were set to zero (i.e. MTR < 0 or MTR >1). Mean regional MTR values from n = 4 healthy volunteers were calculated from 10 $mm^2$ circular ROIs at similar locations in clearly identified homogenous tissue, avoiding blood vessels.

**Results and Discussion:** Representative standard MTR and MT-IDEAL ratio maps are shown in Figure 1 with associated maps of the water signal, fat distribution and $T_2$* values. Mean MT values (± standard error of the mean) acquired from the sample of healthy volunteers using the standard MT and MT-IDEAL paradigms are given in Table 1. Values between the two techniques are noted to be similar in all tissues including the healthy liver, where fat accumulation is expected to be low. A difference is observed with both standard MT and MT-IDEAL values between the anterior and posterior measurements. The MT-IDEAL dataset resulted in signal loss artifacts around gas filled organs such as the stomach likely due to dephasing of spins at later echoes. Furthermore, it can be seen that standard MT values are lower than has been previously reported [3], possibly as a result of different implementations or a reduced transmit efficiency across the subject using the wide-bore MR system.

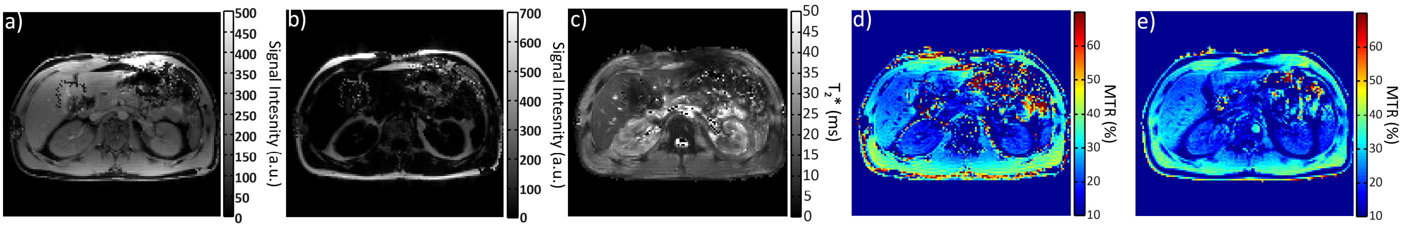


Figure 1- Representative data from a healthy subject illustrating a) distribution of water signal (MT off), b) fat separated image, c) regional $T_2$* values, d) resultant MT-IDEAL MTR map, and e) separately acquired standard MTR map.

| Structure | Standard MT (%) | MT-IDEAL (%) |
|---|---|---|
| Pancreas | 22.3 ± 2.4 | 21.9 ± 1.5 |
| Anterior Liver | 21.9 ± 1.6 | 23.9 ± 2.9 |
| Posterior Liver | 28.2 ± 0.8 | 28.5 ± 1.7 |
| Left Kidney (Cortex) | 18.7 ± 0.5 | 18.7 ± 1.2 |
| Right Kidney (Cortex) | 19.7 ± 1.2 | 19.2 ± 1.4 |
| Left Paraspinal Muscles | 28.0 ± 0.6 | 28.6 ± 1.0 |
| Right Paraspinal Muscles | 27.4 ± 0.3 | 27.8 ± 0.8 |

Table 1- Calculated mean MTR values (± SEM) in various abdominal tissues from n = 4 subjects (age range: 26 – 42 years) using the standard MT and MT-IDEAL paradigms. Values calculated for the pancreas are from sample size n = 3.

**References:**

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