Lamellar liquid crystal phantoms for MT- calibration and quality control in clinical studies

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Introduction: We are investigating the use of magnetization transfer (MT) as a surrogate biomarker for fibrosis in patients with Crohn's Disease (CD). After demonstrating that MT helps differentiate inflammation from fibrosis in a rat model of CD [1], we are now translating these findings to clinical studies. The number of MT acquisitions (different offset frequencies and power levels) is limited by patient time and SAR for clinical studies. A stable and well-characterized MT-phantom will assist in quality control and standardization of MT imaging protocols across multi-vendor/multi-sites MR platforms. This work examines the use of lamellar liquid crystal (LLC) systems as viable MT-phantom for clinical application. LCCs are readily available and possess desired MT-phantom properties: stable, non-toxic, easy to store, have sufficient MT effect, and provide reproducible results.

Methods: Commercially available LLCs (hair conditioners) were used. Our phantom was prepared by transferring Kirkland Signature Hydrating Conditioner (Costco Wholesale Corp, Seattle, WA, USA) into either 15 ml centrifuge tubes or sealed plastic bags. A similar procedure was performed for Suave Daily Clarifying Conditioner. The Suave product has significantly less high molecular weight components than the Kirkland product and minimal MT effect, serving as a negative control.

Samples were studied on a research animal imaging system at 22 and 40 °C at 2T. CW RF irradiation (10 sec) was applied at 4 RF power levels (between 1 and 10 μT) and 19 off-resonance frequencies. Data fitting with a Gaussian line shape for the solid component and MT parameters were estimated by least-square fitting (Fig.1) [2].

For clinical studies, a 3D, gradient-echo, breath-hold pulse sequence was adapted for MT imaging of the bowel at 1.5 T (Philips Healthcare). MT RF pulses (1 kHz off-resonance, 900° flip angle) were applied prior to read-out. Patients scheduled for MR enterography (MRE) were consented for the MT MRE study. SAR was typically less that 3.5 W/kg.

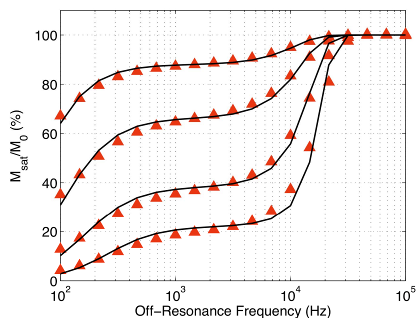

Fig. 1. MT data (red triangles) and fitted theory (black lines) for Kirkland gel. MT parameters were Ra = 0.33 Hz, Rt = 24.1 Hz, Mb0=0.08, and T2b =21.2 μs.

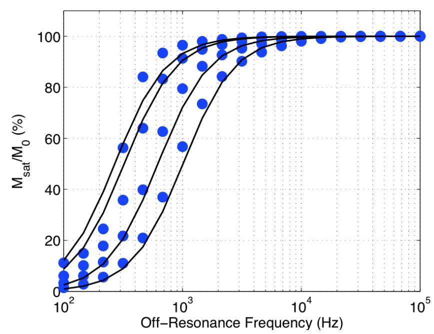

Fig. 2. Data collected (blue circles) from the MT- Suave sample. MT theory failed to find a good fit to the data because of insufficient solid component.

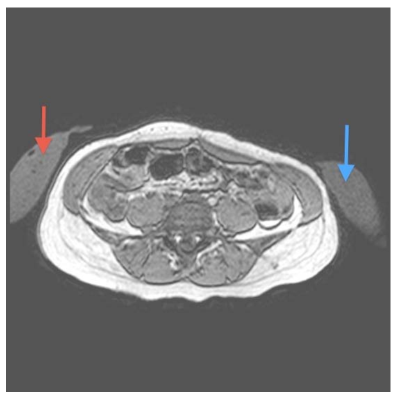

Fig. 3 Typical MT MRE image acquired with TR/TR=3.9/1.83 ms. The bag in the upper left (red arrow) is MT+ gel (Kirkland) and the bag in the upper right (blue arrow) is MT- gel (Suave).

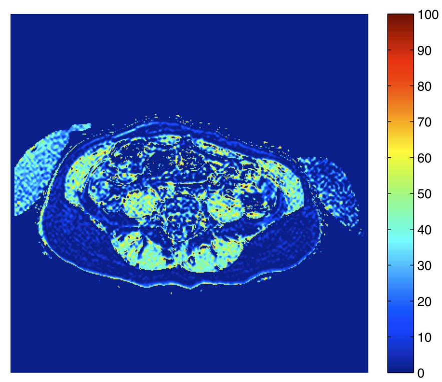

Fig. MTR = 100 (1-Msat/M0). The measured saturation in the MT+ gel is 35% and the measured saturation in the MT- gel is 7%.

Results: Significant MT is seen in Fig. 1 in the MT+ gel. Only direct saturation is observed in the MT- gel (Fig. 2). Fig. 3 and 4 demonstrates show a typical MT MRE image and MTR (MT ratio) image calculated from the 3D gradient-echo sequence with and without RF saturation. The MT+ gel showed MTR of 35% and the MT- gel direct saturation of 7%.

Discussion: The hair conditioners contain long chain fatty alcohols and long chain quaternary ammonium salts that, when emulsified in water, form bilayer lamellar structures. Hair conditioners have many desirable properties for phantom materials. They are readily available, chemically stable, non-toxic, highly formulated, and can be easily formed to any desired shape. Knowledge of fundamental MT parameters (Fig. 1) allows calculation of effective CW MT at any RF power. Results are reproducible for clinical studies done months apart and for MT at different sites. We are currently using the phantoms to evaluate scanner-to-scanner variability at our institution.

Conclusions: The developed MT-phantom helps monitor MRI system performance and stability during clinical studies.

References: [1] Adler J et al. Radiology. 2011;259(1):127-35. [2] Henkelman RM, et al. Mag. Reson. Med. 1993;29(6):759-66.