

Quantification of intragastric fat distribution using IDEAL

Dian Liu¹, Jelena Curcic^{1,2}, Andreas Steingoetter^{1,2}, and Sebastian Kozerke¹

¹Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Switzerland, ²Division of Gastroenterology and Hepatology, University of Zurich, Zurich, Switzerland

Introduction: The increase in food- and nutrition-related diseases over recent years has prompted an increase in research efforts to understand how food emulsion systems are sensed, processed and digested in the gastrointestinal (GI) tract. MRI has evolved as a promising imaging modality to separate water and fat based on multi-echo acquisitions and to visualize aspects of human GI function using dynamic imaging [1]. A recent investigation showed that the quantification of fat fraction using the 2-point DIXON technique provides only limited quantitative information [2]. For accurate fat quantification, all relevant chemical shift species have to be modeled and, accordingly, data at a sufficient number of echo times need to be acquired. In order to derive quantitative water and fat maps, hierarchical IDEAL, which has been shown to be robust against B_0 inhomogeneity effects [3], may be employed. The objective of the present work was to validate and implement hierarchical IDEAL for measuring intragastric fat distribution of tailored lipid emulsions in vitro and in vivo.

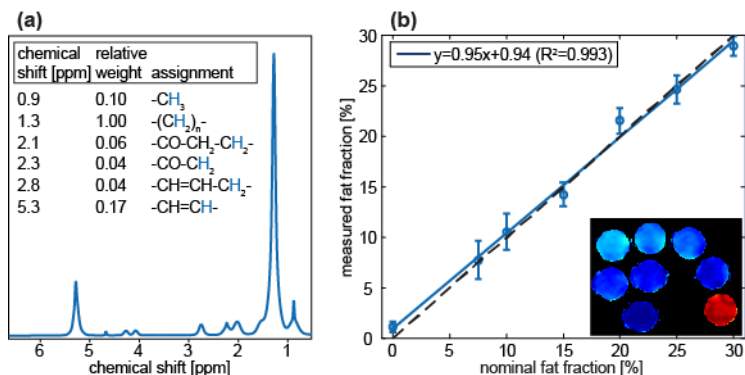


Figure 1: (a) Measured spectrum of rapeseed oil with 6-peak fat model and (b) fat fractions with standard deviations measured in vitro and identity reference line (dashed black line). Color image shows the fat fraction image of the sample.

Meal: Two types of fat emulsion test meals were prepared. The first emulsion was only used for in vitro experiments and consisted of water, medium-chain triglyceride oil, whey protein isolate and phosphate buffer at varying fat fractions of 7.5-30% (droplet size $\sim 0.2\mu\text{m}$). The second emulsion was used in vitro as well as in vivo and was prepared with water, rapeseed oil, xanthan and polysorbate 80, yielding in fat fractions of 24-29% (droplet size $\sim 30\mu\text{m}$).

In vitro: For modeling of the fat chemical species, both oils were measured on a 3T whole-body scanner (Ingenia, Philips Healthcare, Best, the Netherlands) using PRESS. Data were analyzed using the 'lipid-8' setting in LCModel [4]. The resulting fat model was then incorporated into IDEAL. Results were compared to the known fat fractions as a reference.

In vivo: Three healthy volunteers were imaged in supine position with in vitro samples attached to the front as a reference. After drinking 180ml of the test meal, the sequences were performed every 15 minutes.

Results: From the spectroscopic measurements, a 6-peak fat model was generated with different weights for the first and second emulsions. The spectrum and peak model for rapeseed oil is shown in Fig.1a with peaks assigned according to [5]. Fig.1b shows the accuracy between reference and 6-point IDEAL for the in vitro samples. In vivo, representative fat fraction images acquired 4 and 60 minutes after meal intake are depicted in Fig.2. The phenomenon of 'fat layering' and its temporal development are clearly seen. The measured gastric content volumes and calculated fat volumes of the three volunteers are presented in Fig.3. In comparison to the total gastric content volumes contoured on balanced SSFP images, the total gastric content volumes on IDEAL images were underestimated by $(9.5 \pm 8.6)\text{ml}$ on average. This may be explained by reduced partial volume effects in the balanced SSFP images due to higher resolution.

Discussion: Important aspects of gastric physiology involving the quantitative analysis of intragastric distribution, mixing and emptying of fat in emulsions can be assessed in a single breath hold of 30s using 6-point IDEAL. Detected fat fractions were in agreement with the in vitro samples. An increase in resolution of IDEAL images for a more accurate volume segmentation is limited by breath hold constraints but may be overcome by employing undersampling schemes.

References: [1] Marciani L Neurogastroenterol Motil 2011;23:399-407.

[2] Hussein M et al. ISMRM 2013.

[3] Tsao J et al. MRM 2013;70:155-59.

[4] Provencher S MRM 1993 ;30 :672-79.

[5] Hamilton G et al. JMRI 2011;34:468-73.

Methods: Phantom and in vivo experiments were conducted on a 1.5T whole-body MRI scanner (Achieva, Philips Healthcare, Best, The Netherlands) with a standard 4-element coil array. Multi-echo data were acquired using a 6-point gradient-echo sequence with flyback gradients, TR=10ms, first TE=1.25ms, TE spacing=1.54ms, flip angle=15°, FOV=360x260mm², voxel size 2.0x2.3mm², slice thickness 8mm, scan duration 1.5s/slice. For each scan, 20 transversal slices were acquired in one breath hold to cover the complete stomach volume. Hierarchical IDEAL was used to reconstruct water and fat images. Fat fraction images were calculated by taking the ratio of fat and water maps. The resulting images were analyzed to assess gastric emptying of the aqueous and lipid phase by semi-automatic segmentation of gastric content. Standard balanced SSFP volume scans (voxel size 1.5x1.9mm², slice thickness 6mm, scan duration 0.5s/slice, 30 transversal slices) were performed interleaved with the multi-echo acquisitions to compare the accuracy of volume detection based on fat fraction images.

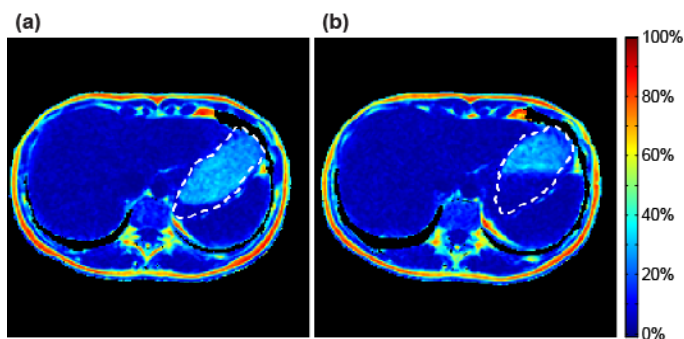


Figure 2: Representative image slice of a fat fraction image at 4 (a) and 60 minutes (b) after meal intake with the contoured total gastric content shown by the dashed white line. A fat layer is formed on top of gastric content, which decreases over time. Color indicates fat fraction in percent.

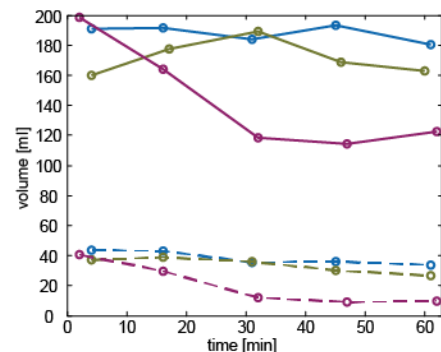


Figure 3: Total gastric content volume (solid line) and fat volume (dashed line) of the three subjects. Due to the dependency of total gastric volume on the amount of produced secretion, subject 2 (green line) has maximum gastric content after 30 minutes.