Multiecho Water-Fat Separation with Navigated Free-Breathing 3D Spoiled Gradient-Recalled Echo Sequence

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Target Audience: Scientists, engineers and radiologists who have an interest in water-fat separation methods in abdomen.

Purpose: Multiecho water-fat separation with multifrequency fat spectrum modeling (IDEAL IQ) provides accurate estimates of fat fraction. [1] One of the most suitable organs for this technique is the liver, whose fat is the hallmark feature of nonalcoholic fatty liver disease. Navigator gating technique enables free-breathing T1 weighted abdominal imaging of patients who have difficulty in breath-holding such as infants, [2] and it also enables high spatial resolution imaging which takes a long scan time beyond breath-hold. [3] In this work, we developed respiratory gated IDEAL IQ with navigator echo for free-breathing image acquisition of the liver.

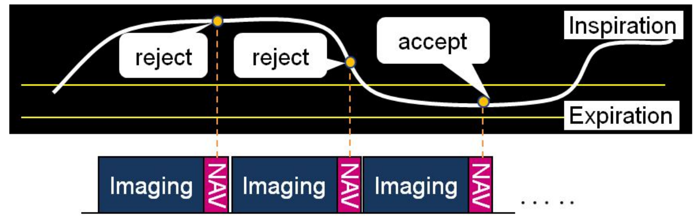

Fig. 1 Timing diagram for navigator gated IDEAL IQ. The white and the yellow lines represent the movement of the diaphragm and the acceptance window, respectively.

Methods: *Pulse Sequence Design:* Figure 1 shows the timing diagram of navigator gated IDEAL IQ. A navigator is inserted after imaging block and imaging data is accepted only when the accompanying navigator value falls within the acceptance window. The imaging block consists of 6-point 3D multiecho spoiled gradient recalled echo (SPGR) sequence to measure fat content. The effect of navigator insertion on SPGR signals were examined in simulation with 6.2 ms TR, 25 ms navigator duration and 28 SPGR excitations per navigator echo.

Data Acquisition: We used investigational version of IDEAL IQ sequence and collected 6-point images with and without navigator gating. The navigator consisted of a 2D pencil-beam excitation with a 20° flip angle, 10cm length, 2cm width, and 256 readout points. We performed all scans on GE 3.0 T Discovery MR750w MR imaging system (GE Healthcare, Waukesha, WI, USA) with an 8-channel body array coil. We used eight gel phantoms with different contents of peanut oil. In human study, navigator was placed on the right hemi-diaphragm and informed consent was obtained for human scanning.

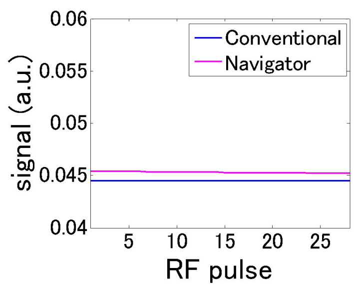

Fig. 2 SPGR signals simulation. The signal values correspond to the transversal magnetizations immediately after the SPGR RF excitations in the 20th iteration of imaging block.

Results: In simulation, navigator insertion caused the signal differences of the first and last signals in imaging block due to T1 relaxation during navigator pulse sequence execution (Figure 2), but the difference was small (0.48%). Phantom experiments showed that navigator-gated IDEAL IQ reproduced fat fraction values calculated with conventional IDEAL IQ (Figure 3). In volunteer scan, free-breathing navigator-gated IDEAL IQ had similar image quality as conventional breath hold method, without motion related artifacts (Figure 4a,b). Moreover, navigator gated IDEAL IQ enables high resolution fat fraction map (Figure 4) with a prolonged scan time (6min).

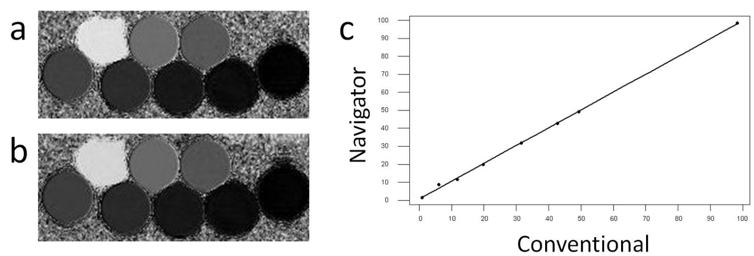

Fig. 3 Phantom fat fraction maps of (a) conventional and (b) navigated IDEAL IQ and (c) regression plot of the values of the two methods. The regression equation is: $fat_{nav} = 0.759 + 0.990\ fat_{con}$, and adjusted R^2 is 99.9%. Fat_{nav} and fat_{con} mean fat fraction values (%) calculated with navigated and conventional IDEAL IQ, respectively. Imaging parameters included: TR/TE = 10.4 ms/3.4 ms, BW = ±111.1 kHz, FOV = 30 cm x 30 cm, slice thickness = 4.0 mm, matrix = 160 x 160.

Discussion: In this work, we demonstrated navigator insertion does not disrupt fat fraction estimation. Residual motion artifacts can effect on its fraction, so optimum navigator settings, such as acceptance window range, are to be investigated in future.

Conclusion: We have demonstrated that navigated IDEAL IQ enables free-breathing fat content estimates of the liver. This may be useful fat measurement application for patients who cannot hold their breath.

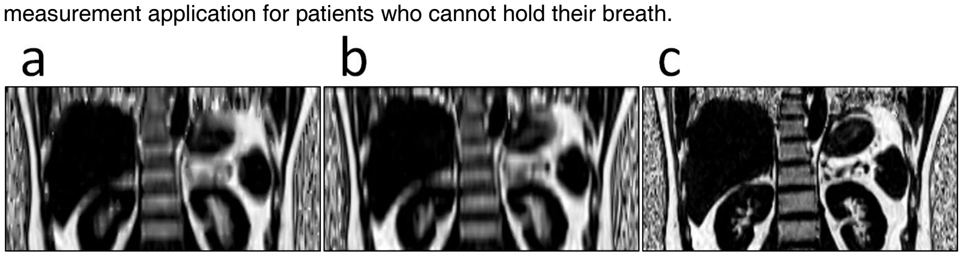

Fig. 4 Volunteer fat fraction maps of (a) conventional and (b,c) navigated IDEAL IQ in reformatted coronal plane. Imaging parameters of (a) and (b): TR/TE = 6.6 ms/2.9 ms, BW = 111.1 kHz, FOV = 44 cm x 26.4 cm, slice thickness = 10.0 mm, matrix = 160 x 96. Imaging parameters of (c): TR/TE = 8.9 ms/4.0 ms, BW = ±111.1 kHz, FOV = 44 cm x 26.4 cm, slice thickness = 4.0 mm, matrix = 256 x 134.

References: 1. Yu H, McKenzie CA, Shimakawa A, et al. Multiecho reconstruction for simultaneous water-fat decomposition and T2* estimation. J Magn Reson Imaging. 2007;26(4):1153-1161.

2. Vasanawala SS, Iwadate Y, Church DG, et al. Navigated abdominal T1-W MRI permits free-breathing image acquisition with less motion artifact. Pediatr Radiol. 2010;40(3):340-344.

3. Nagle SK, Busse RF, Brau ACS, et al. High resolution navigated three-dimensional T1-weighted hepatobiliary MRI using gadoxetic acid optimized for 1.5 tesla. J Magn Reson Imaging. 2012;36(4):890-899.