In vivo liver ^{1}H MRS measurement of PDFF, and T1 and T2 of water and fat, in a single breath-hold with multiple TRs and TEs.

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Target Audience: The abstract is aimed at radiologists and physicists with an interest in liver fat quantification and characterization.

Purpose. *In vivo* hepatic Proton Magnetic Resonance Spectroscopy (^{1}H MRS) can accurately measure proton density fat fraction (PDFF) by acquiring single-average spectra with long TR (> 3000 ms) at multiple TEs to provide a T1-independent, T2-corrected fat fraction. However, the requirement to acquire spectra in a single breath-hold severely limits the number of TEs that can be collected, reducing the accuracy of T2 measurement. Reducing TR to allow collection of spectra at more TEs introduces T1 weighting into the PDFF estimate, requiring T1 measurement. Here we propose acquiring single-average spectra at multiple TRs and TEs in a single breath-hold to confirm that this sequence can repeatably measure liver water and fat T1 and T2, and PDFF *in vivo*.

Methods. *In vivo* ^{1}H MR spectra were acquired at 3 Tesla (GE Signa EXCITE HD, GE Healthcare, Waukesha, WI) using an 8-channel torso array coil in 29 subjects. After conventional imaging, a 20 x 20 x 20 mm voxel was selected within the liver that avoided liver edges and major blood vessels. A Stimulated Echo Acquisition Mode (STEAM) sequence was used with minimum mixing time (TM 5 ms) to reduce j-coupling effects. The bandwidth was 5000 Hz, and 256 data points per spectrum were acquired with no water or spatial saturation. The MRS voxel was shimmed during free breathing. Sequence timings, detailed in **Table 1**, were designed to provide sufficient TR and TE range to accurately measure T1 and T2 of water and fat within a single breath-hold. A total of 32 spectra (including four pre-pulse acquisitions) are acquired in a 21 s breath-hold. Following the four pre-pulses, the TR was altered between 150-2000 ms for 20 spectra with a fixed TE of 10 ms. Then, from spectra 20 onwards, the TR is fixed at 1000 ms and TE is increased from 10 to 110ms. To examine the repeatability of the values measured by this sequence, the sequence was run twice in the same voxel. The spectra from the individual channels were combined using a singular value decomposition based approach (**1**). A single experienced observer analyzed the spectra using the AMARES algorithm (**2**) included in the MRUI software package (available from www.mrui.uab.es). Results were saved in a text file and analyzed in a custom Matlab routine that non-linearly minimizes the difference between peak area and the peak given by the standard equation $S = S_0\left(1 - \exp\left(-\frac{TR}{T1}\right)\right).\exp\left(-\frac{TE}{T2}\right)$. T1 and T2 were calculated for water (4-6 ppm) and fat (0-3 ppm). PDFF was corrected for the fat included 'in' the water peak from a previously established standard liver spectrum (**3**).

Table 1: The sequence timing of the proposed sequence. P1-P4 are pre-pulse excitations. Scan time 20.95 s.

Spect No.	**P1**	**P2**	**P3**	**P4**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
TR (ms)	150	150	150	150	150	225	300	400	600	900	2000	1500	700	450	325	250
TE (ms)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Spect No.	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
TR (ms)	175	200	275	350	500	800	1250	1000	1000	1000	1000	1000	1000	1000	1000	1000
TE (ms)	10	10	10	10	10	10	10	10	15	20	25	30	50	70	90	110

Results. Typical T1 and T2 recovery curves for water and fat are shown in **Figure 2** and **Figure 3**. The 1st and 2nd measurements of T1 and T2 for water and fat are compared in **Figure 3** and **Figure 4**. In these figures, only subjects with PDFF > 5% (n = 12) have fat T1 and T2 displayed, as at low fat levels there is insufficient fat signal to measure fat T1 and T2. **Figure 5** compares the 1st and 2nd measurements of PDFF. In all figures, the dotted line indicates unity.

Conclusion. The multi TR-TE sequence measures T1, T2 and PDFF with high repeatability *in vivo*.

Refs: 1) Bydder M, Magn Reson Imaging 2008; 26: 847-850. **2)** Vanhamme L, J Magn Reson 1997; 129: 35-43. **3)** Hamilton G, NMR Biomed 2011; 24: 784-790.

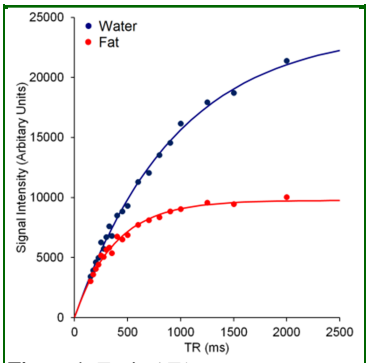

Figure 1: Typical T1 recovery curves for water and fat.

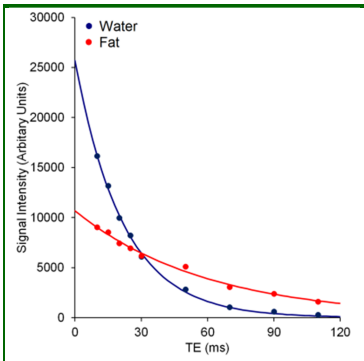

Figure 2: Typical T2 recovery curves for water and fat

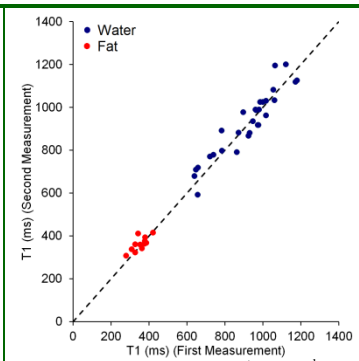

Figure 3: Comparison of 1st and 2nd measurements of water and fat T1.

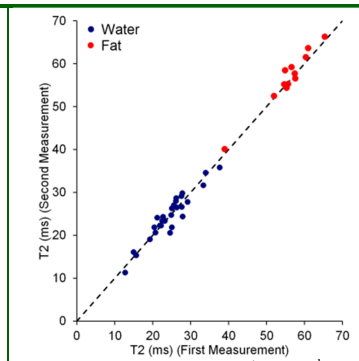

Figure 4: Comparison of 1st and 2nd measurements of water and fat T2.

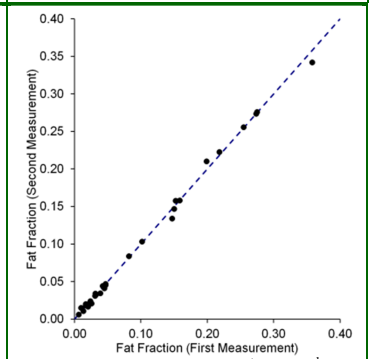

Figure 5: Comparison of 1st and 2nd measurements of PDFF.