Repeatability of measurement of liver T1, T2 and PDFF by multi-TR, multi-TE single breath-hold ^{1}H MR spectroscopy.

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Target Audience: Radiologists and physicists with an interest in liver fat quantification and characterization

Introduction: We have developed a rapid multi-TR, multi-TE ^{1}H MRS sequence for *in vivo* hepatic fat quantification and characterization that acquires 32 single-average spectra in a single breath-hold (**Table 1**), allowing collection of liver proton density fat fraction (PDFF), and water and fat T1 and T2 values. Here we examine the intra-examination repeatability of the quantities measured by this sequence.

Methods: *In vivo* liver ^{1}H MR spectra were acquired without contrast at 3 Tesla (GE Signa EXCITE HDxt, GE Healthcare, Waukesha, WI) using an 8-channel torso array coil in 64 adult subjects between January 2012 and September 2014. A 20 x 20 x 20 mm voxel was selected within the liver, avoiding liver edges and major blood vessels. Thirty-two spectra (including four preparatory acquisitions) were acquired in a 21 s breath-hold using a modified Stimulated Echo Acquisition Mode (STEAM) sequence (timings in **Table 1**). A minimum mixing time (5 ms) was used to reduce j-coupling effects. Bandwidth was 5,000 Hz, and 256 data points per spectrum were acquired with no water or spatial saturation. The selected voxel was shimmed during free breathing. The sequence was repeated in the same location three times without repositioning the patient.

Table 1: Sequence timing of the multi TR-TE 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

Spectra from individual channels were combined using singular value decomposition (**1**). A single experienced observer analyzed the spectra using the AMARES algorithm (**2**) included in the MRUI software package (**3**). The results were analyzed with a custom Matlab routine that non-linearly fitted measured peak area to 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) as well as the individual fat spectral peaks; PDFF was corrected for fat included in the 'water' peak from a previously-established standard liver spectrum (**4**). Intraclass correlation coefficient (ICC) was used to estimate the repeatability of the PDFF and water and fat T1 and T2 for the three spectral acquisitions. For fat T1 and T2, only values from subjects with a mean PDFF > 5% (n = 39) were used in the ICC calculations.

Results: A typical multi-TR-TE acquisition is shown in **Figure 1**. The multi-TR-TE sequence showed very high levels of repeatability when measuring PDFF (ICC = 0.999) (**Figure 2**), water T2 (ICC = 0.920) (**Figure 3**) and water T1 (ICC = 0.845). For subjects with mean PDFF > 5%, there was good repeatability for fat T2 (ICC = 0.796), but there was only moderate agreement between the measurements of fat T1 (ICC = 0.564).

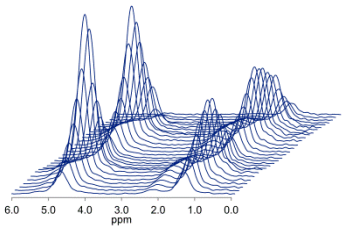

Figure 1: Multi-TR-TE Acquisition in a 62 yr-old woman with PDFF 27.6%. Pre-acquisitions excitations not shown.

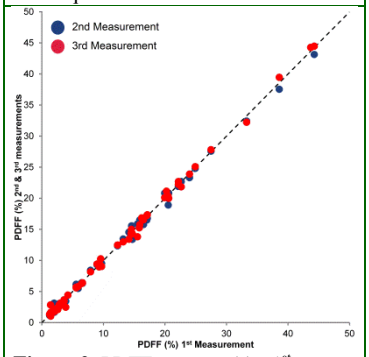

Figure 2: PDFF measured by 1st spectral acquisition compared to that measured by 2nd and 3rd acquisitions

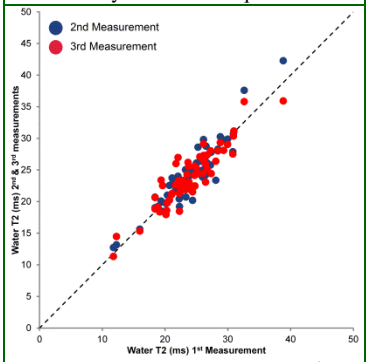

Figure 3: Water T2 measured by 1st spectral acquisition compared to that measured by 2nd and 3rd acquisitions.

Discussion: In conclusion, this study showed that in a single breath-hold, water T1 and T2, fat T2, and PDFF can be measured with high repeatability using the multi-TR-TE sequence. Repeatability for fat T1 was modest; it is possible that shortening the minimum TR used in the sequence will improve fat T1 measurement repeatability. By making it possible to acquire this data in a single breath hold, the multi-TR-TE sequence may provide new opportunities to characterize and monitor liver disease.

Refs: 1) Bydder M, Magn Reson Imaging 2008; 26: 847-850. **2)** Vanhamme L, J Magn Reson 1997; 129: 35-43. **3)** Naressi A. MAGMA 2001; 12: 168-76. **4)** Hamilton G, NMR Biomed 2011; 24: 784-790