Measuring T_2 and T_1 simultaneously in the abdomen using T_2-prepared bTFE at 3T

E. F. Cox[1], C. L. Hoad[1], and P. A. Gowland[1]

[1]Sir Peter Mansfield Magnetic Resonance Centre, School of Physics & Astronomy, University of Nottingham, Nottingham, Nottinghamshire, United Kingdom

Introduction

A technique that could measure T_2 and T_1 simultaneously in the abdomen in an acceptable time would have significant benefits for investigating the gastrointestinal (GI) tract, e.g. to provide a quantitative measure of changes in tissue either due to normal function or to pathology. Changes in GI contents, such as dilution and viscosity changes, can also be monitored using T_1 and T_2 respectively[1,2]. However, it is often difficult to measure T_1 and T_2 accurately using the same sequence and in a reasonable time because of sensitivity to flip angle errors[3,4]. Images of high SNR with minimal distortions particularly in the abdomen can be produced using the balanced turbo field echo sequence (bTFE or TrueFISP). bTFE is particularly useful in the abdomen at 3T where EPI techniques are affected by susceptibility artifacts and HASTE or RARE techniques have a very high SAR. We have previously shown that it is possible to measure T_2 using bTFE with a suitable preparation phase (T_2-prep bTFE)[5]. This work aims to show that T_1 and T_2 can be measured simultaneously using T_2-prepared bTFE by adjusting the sequence timing and bTFE flip angles, and hence to measure the transverse and longitudinal relaxation times of abdominal tissues at 3T in normal subjects.

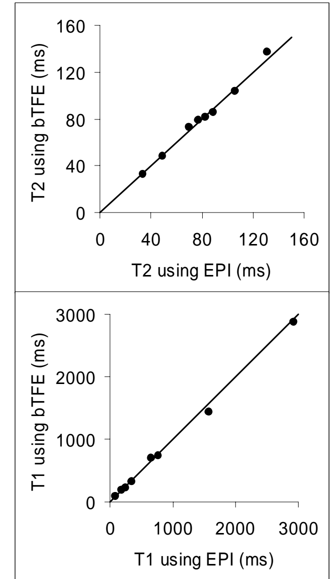

Figure 1: Phantom calibration for T_2-prep bTFE against single shot EPI (identity line shown)

The T_2-prepared bTFE sequence

The sequence consisted of a {90º-TE/2-180º-TE/2-90º} pulse T_2-preparation phase followed by a half Fourier bTFE acquisition block consisting of a $\alpha^o/2$ preparation pulse and successive alternating $\pm\ \alpha^o$ pulses with a TR of 3ms. There was a time delay of 15 s at the end of the bTFE acquisition to allow the system to fully relax to maximize SNR and avoid having to take account of longitudinal suppression between shots in the fit. The signal intensity at the centre of k-space was measured for several TEs at 3 different bTFE flip angles. The fitting program modelled the signals by repeated application of rotation (1) and relaxation (2) functions:

$$M_x(t)=M_x(0) \qquad M_y(t)=M_y(0)\cos(\alpha)+M_z(0)\sin(\alpha) \qquad M_z(t)=-M_y(0)\sin(\alpha)+M_z(0)\cos(\alpha) \qquad (1)$$

$$M_x(t)=M_x(0)\exp(-t/T_2) \qquad M_y(t)=M_y(0)\exp(-t/T_2) \qquad M_z(t)=M_z(0)\exp(-t/T_1)+M_0(1-\exp(-t/T_1)) \qquad (2)$$

(Eq. 2 does not include additional rotation due to off resonance which was not taken into account). The Powell algorithm[6] was used to minimise the difference between the measured and modelled data in order to fit T_2, T_1, M_0 and β. The T_2-preparation pulses are non-ideal and so a β term was also included in the fit for experimental data as {β.90º - TE/2 - β.180º - TE/2 - β.90º} for the T_2-preparation phase.

Imaging Methods

Imaging was carried out on a 3T Philips Achieva whole body MRI scanner using the SENSE Torso coil. The T_2-prep bTFE sequence was implemented with half Fourier acquisitions to increase sensitivity to the preparation phase for both phantom and in vivo experiments. IR-EPI and SE-EPI were used as the gold standard techniques, since if they are run with a long TR they are insensitive to RF pulse errors for both T_1 and T_2 measurements.

Calibration: 2 spherical phantoms, divided into quadrants containing NaCl and 8 different concentrations of agar gel and Gadolinium ions were scanned using the T_2-prep bTFE sequence and both SE and IR single shot EPI sequences. T_2-prep bTFE decay curves were generated at α=30° using 19 different TEs (0.02-10s) and also at α = 15° & 45° at TE = 2s and 8s (T_2-prep bTFE imaging time = 6mins). The data was fitted using the minimization technique described above. A non-linear fit was used to measure T_1 from the IR-EPI data and a linear log fit was used to measure T_2 from the SE-EPI data, correcting for background noise in the lowest signal to noise images.

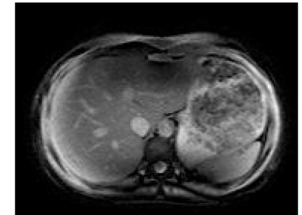

Figure 2: Transverse slice using T_2-prep bTFE at TE=20ms

In vivo: 5 healthy volunteers (24-44 years) were scanned on a single occasion and measurements of T_2 and T_1 in several abdominal tissues were acquired from 2 different slices (1 transverse, 1 coronal) through the abdomen. T_2-prep bTFE decay curves were generated at α=30° using 19 different TEs (0.02-10s) and also at α = 10° & 20° at TE = 2s and 8s (T_2-prep bTFE imaging time = 6mins). The same minimization technique was used to obtain T_2 and T_1 from the T_2-prep bTFE data. Regions were drawn in both kidneys, and in the liver and spleen in both the transverse and coronal plane where possible. It was not possible to distinguish between the cortex and the medulla in the kidney due to the slice chosen.

Results

Calibration: Fig. 1 plots the measured T_2 and T_1 values from each quadrant of the phantoms from T_2-prep bTFE against EPI (SE and IR respectively).

In vivo: Fig. 2 shows a typical transverse image obtained for the shortest TE used (TE=20ms). Table 1 shows the mean T_2 and T_1 values measured in the 5 volunteers.

	T_2 (ms)	T_1 (ms)
Kidney	77 ± 7	1714 ± 257
Liver	32 ± 6	985 ± 143
Spleen	58 ± 12	1519 ± 160

Table 1: T_2 and T_1 (in ms) values for N=5 (mean ± std. dev)

Conclusions

There was good agreement in the measured relaxation times between EPI and T_2-prep bTFE in the phantom and the *in vivo* data compares well with the literature[7]. By having a single imaging sequence to measure T_2 and T_1, the analysis process is simplified and is more time efficient than using separate imaging sequences for the measurements. Further work will optimise the SNR per unit time in terms of both the number and values of TEs used to minimize the total imaging time. This sequence will be incorporated into GI studies where it is often important to be able to measure the dilution of contrast agents or food stuffs in the GI tract.

References 1. L Marciani *et al*. J. Nutr. **130**, 122-7 (2000), 2. CH Hoad *et al*. J. Nutr. **134**, 2293-300 (2004), 3. CA McKenzie *et al*. MRM. **41**, 208-12 (1999), 4. CS Poon *et al*. JMRI. **2**, 541-53 (1992), 5. CL Hoad. *et al.* Proc. ISMRM P2506 (2006), 6. WH Press *et al.* Num. Rec. in C (2nd Ed.), 7. CMJ de Bazelaire *et al*. Radiol. **230**, 652-9 (2004).

Acknowledgements This work was funded by the University of Nottingham and a grant from the MRC in partnership with EPSRC.