Validation of clinically useful fast, multi slice, multi echo T2 quantification sequence.

S. V. Swaminathan[1,2], C. L. Tosti[2], K. Hultman[2], J. H. Jensen[3], A. Nunez[3], E. X. Wu[4], S. Sheth[5], G. M. Brittenham[5], and T. R. Brown[2]

[1]Clinical Science, Philips Medical Systems, Cleveland, OH, United States, [2]Radiology, Columbia University, New York, NY, United States, [3]Radiology, New York University, New York, NY, United States, [4]Electrical & Electronic Engineering, University of Hong Kong, Hong Kong, Hong Kong, [5]Pediatrics, Columbia University, New York, NY, United States

Introduction

To improve the assessment of tissue iron in patients with iron overload, we have developed and validated a new fast, multi slice, multi echo method for quantification of T_2. Sequences currently used for T_2 measurements are either single slice acquisition with multiple echoes (SS-ME) and composite refocusing pulses (1) or multi slice single spin echo (MS-SE) (2) based techniques. The shortest echo time (TE) achieved with these sequences is 6 ms (3). Shorter TEs would help to better define the exponential behavior of T_2 relaxation, especially in tissues with higher storage iron concentrations. In practice, scan times of one-slice sequences are long, restricting their incorporation into routine clinical practice. Turbo spin echo (TSE) based sequences are faster but underestimate T_2 due to the presence of stimulated echoes (4). Recently Pell et.al.(5) reported an optimized Carr-Purcell-Meiboom-Gill (CPMG) multi-echo sequence that minimizes the influence of stimulated echoes from imperfect refocusing pulses. Here we report our further development and validation of an optimized multi-echo (OpME) sequence for multi slice acquisition that is fast and clinically useful for measurement of T_2 in iron-loaded tissue. It is important that the validation of the technique should be done on phantoms that mimic the T_1 and T_2 of the tissue of interest (4). Hence for our validation studies, we chose $MnCl_2$ phantoms because Mn primarily affects T_2 rather than T_1.

Materials and Methods

All the measurements were performed on a Philips 1.5 T Intera scanner equipped with a five-element phased array coil at the Hatch Center for NMR Research at the Columbia University Medical Center. The sequences were validated on $MnCl_2$ phantoms of concentration ranging from 0.135 mM to 0.675 mM in steps of 0.135 mM. Liver studies *in vivo* were carried out with healthy volunteers. A three-slice OpME sequence with a field of view sufficient to overcome SENSE foldover artifacts was acquired. We used a slice thickness ratio (STR) of 3:1 as recommended by Pell et.al. (5) in all our acquisitions. The slice thicknesses for phantom studies and volunteer examinations were 5 mm and 10 mm respectively. Inter slice gaps of 3 mm for phantom and 6 mm for volunteer measurements were chosen. To further reduce measurement times, OpME acquisitions were performed using SENSE parallel acquisition with a reduction factor of 1.5 along the phase encode direction. I*n vivo* acquisitions were performed with free breathing using real time navigators. 128 x 128 data points were collected and reconstructed along the phase and frequency encode direction. 25 echoes with a TE of 4 ms and an echo spacing of 4 ms were acquired for the OpME scan. The minimum TE possible for the SS-ME acquisition was 8 ms. SS-SE, SS-ME and one-slice OpME scans were also acquired for comparison. The repetition time (TR) of 1 sec for all scans resulted in a scan time of about 3 min and 1 min for SS-ME and OpME respectively.

Results

Scatter plots were made for SS-ME, one-slice OpME and for the three slices of the 3-slice OpME acquisition. Figure 1 shows the plot of R_2 against concentration for $MnCl_2$ phantoms. A T_2 relaxation plot for normal liver is shown in Figure 2. A linear fit was performed for relaxivity and a mono-exponential fit was done for T_2 relaxation data. We found the relaxivity o be 72 $\pm$ 0.5 s^{-1}/mM for 3-slice OpME scans, 74 $\pm$ 0.5 s^{-1}/mM for 1 slice OpME and 78 $\pm$ 0.4 s^{-1}/mM for SS-ME. Liver measurements *in vivo* yielded a T_2 of 59.2 ms for SS-SE and a mean value of 61.6 $\pm$ 2.2 ms for the 3 slices from OpME scan.

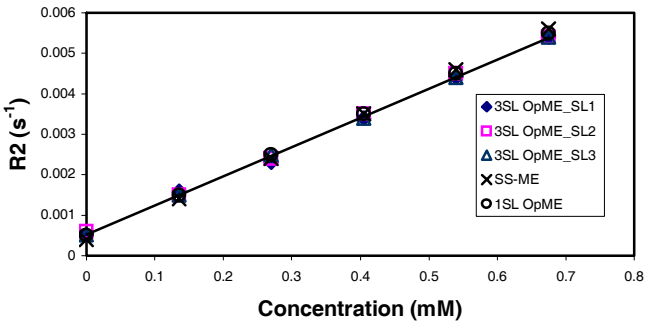

Figure 1: Relaxivity plots of $MnCl_2$ Phantoms. Single slice Optimized multi-echo (1SL OpME) is plotted along with 3-slice OpME for all the three slices and Single slice using block pulse

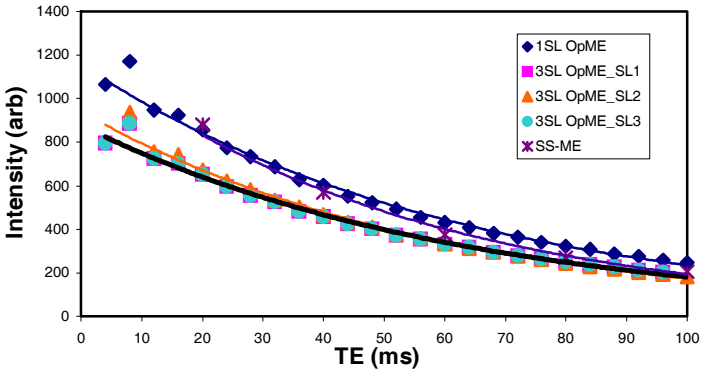

Figure 2: T_2 relaxtion measurement plots for normal human liver. Single slice Optimized multi-echo (1SL OpME) is plotted along with 3-slice OpME for all the three slices and SS-ME

Conclusions

OpME based multi slice scans yielded estimates of the relaxivity of the $MnCl_2$ phantoms and of the T_2 of the normal healthy liver in agreement with published values (6). Our new method reduces the scan time with respect to SS-ME by a factor of 2 to 2.5 and with respect to MS-SE by an even greater extent. The STR approach to optimization reduces the stimulated echo effects considerably but care has to be taken while acquiring multiple slices in order to avoid saturation effects. SENSE parallel acquisition permits a further reduction in scan time. Moreover, the combination of SENSE and a real time navigator-based acquisition strategy provides a higher spatial resolution while avoiding a requirement for breath holding during the measurement. This acquisition strategy under free breathing is clinically more useful for subjects who have difficulty holding their breath. With appropriate modifications, a similar acquisition strategy could be extended to other tissues, including the myocardium. Overall, our results demonstrate that accurate clinical T_2 quantification is possible with MSE based CPMG sequences.

References

1. Poon CS, Henkelman RM. J Magn Reson Imaging 1992;2(5):541-553.
2. St Pierre TG, Clark PR, Chua-Anusorn W. NMR Biomed 2004;17(7):446-458.
3. Wood JC, Enriquez C, Ghugre N, Tyzka JM, Carson S, Nelson MD, Coates TD. Blood 2005;106(4):1460-1465.
4. Williams CF, Redpath TW, Smith FW. Magn Reson Imaging 1996;14(4):419-428.
5. Pell GS, Briellmann RS, Waites AB, Abbott DF, Lewis DP, Jackson GD. J Magn Reson Imaging 2006;23(2):248-252.
6. S Salo AA, R Leino, S Bondestam, M Komu. The British Journal of Radiology 2002;75:24-27.

Acknowledgments:

This work was supported in part by NIH/NIDDK grants R01-DK069373, R01-DK066251 and R01-DK049108