Simultaneous T1, T2 and spin density quantification in 5 seconds using inversion recovery SSFP

C. Stehning[1], S. Winkelmann[1], and H. Dahnke[1]
[1]Philips Research Europe, Hamburg, Germany

Introduction

Measuring MR relaxation constants is essential for diverse applications, including perfusion imaging [1] and contrast agent quantification [2]. Inversion recovery (IR) steady state free precession (SSFP) can be used to measure T1, T2 and RHO simultaneously [3]. However, IR requires wait cycles of several T1 in between successive inversion pulses, which prolongs the scan time, compromises temporal resolution and inhibits monitoring of dynamic processes. This shortcoming is addressed in the present study. Extended acquisition windows and a partial Fourier acquisition allow for the acquisition of all data after one single inversion pulse, i.e., in a single shot. The scan time was reduced to 5 seconds, and unnecessary wait cycles were eliminated completely. Initial *in vivo* experiments were performed. Furthermore, simulations were carried out to evaluate the effect of extended acquisition windows on the precision of the T1 measurement.

Methods

Experiments were performed on a 1.5T clinical MR scanner (Achieva, Philips Medical Systems) using a birdcage head coil. A 2D single shot (5s) inversion recovery SSFP experiment was conducted in 5 volunteers. The following sequence parameters were used: Adiabatic inversion pulse, 2D SSFP acquisition, TR/TE=3.7/1.85ms, α=50°, partial Fourier acquisition (factor 0.625), measured resolution (1.3 x 1.3 x 8) mm³. 16 phases over the inversion recovery signal evolution were measured, resulting in an acquisition window of T_{AQ}=332ms per phase. T1, T2 and RHO maps were calculated from the measured apparent relaxation time, T1*, the ratio of the initial (M_0) and steady state (M_{SS}) magnetization, and the flip angle [3]. Furthermore, simulations were carried out to quantify the effect of T1 recovery during T_{AQ}. For this purpose, a T1 map was obtained from simulated data mimicking (1) an infinitesimal sampling window, and (2) the extended acquisition window T_{AQ} employed in the present study.

Results and discussion

The simulation results are shown in Fig. 1. For the given MR sequence, the extended sampling window does not have a significant impact (ΔT1 < 3%) on the T1 measurement. Selected *in vivo* results are shown in Fig. 2 a-d. T1*, T1, T2 and RHO measured in a user-defined ROI (mean ± standard deviation) are summarized in Table 1. The measured T1, T2 and RHO values closely resemble previous results [3], and other literature values [4] where available.

Conclusion

The present study has shown that using inversion recovery SSFP in concert with extended acquisition windows and a partial Fourier acquisition, quantitative T1/T2 and RHO maps can be measured with good spatial resolution in one single shot. Wait cycles, which are inherent to inversion recovery, can be eliminated completely, and scan efficiency is improved. This is a key benefit for applications requiring a good temporal resolution such as perfusion measurements or other studies on contrast kinetics. Although it was shown that the extended acquisition window only has a minor impact on the T1 measurement, residual deviations could be corrected using an iterative discrete Fourier transformation for image reconstruction [5].

Table 1. Measured relaxation times and spin density (mean ± sd within ROI) in frontal lobe of one volunteer

	T1* [ms]	T1 [ms]	T2 [ms]	ρ [%]
gray matter	328 ± 77	883 ± 116	86 ± 27	73 ± 3
white matter	292 ± 57	852 ± 103	73 ± 17	69 ± 3
CSF	1628 ± 262	3206 ± 246	1523 ± 232	100 ± 4

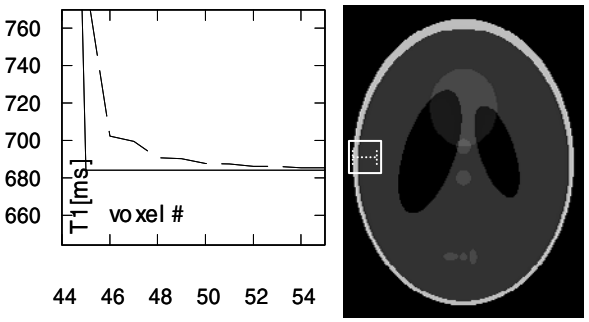

Fig 1. Profile over T1 values calculated from simulated data. Only a section located at a transition between tissues (white box) is shown. Solid line: infinitesimal acquisition window; dashed line: AQ window T_{AQ}=332ms

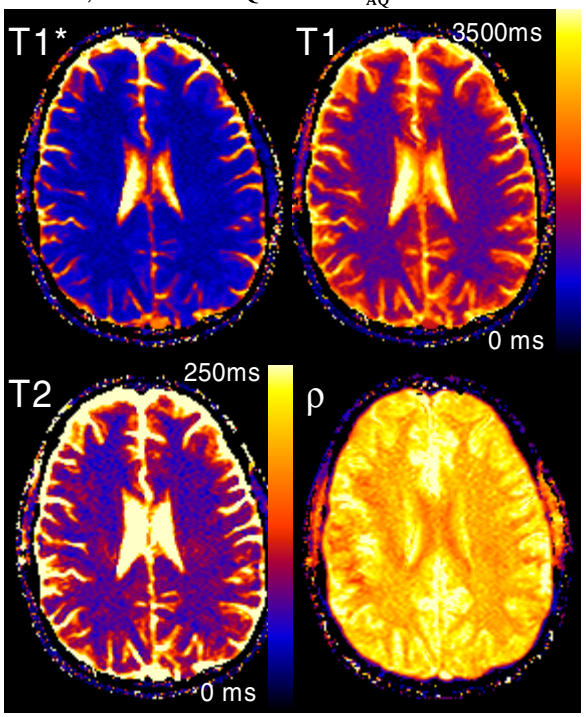

Fig 2. T1*, T1, T2, and RHO maps across the brain (transversal orientation) for one selected volunteer. For better visualization, the T1 and T2 maps were truncated at 3500ms and 250ms, respectively.

References

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