Simultaneous T1 and T2* mapping without B1 correction

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Introduction: Functional magnetic resonance imaging is a powerful tool for investigating a large variety of biological procedures. Thus, the interest in fMRI has continuously grown during the recent years. Two very important parameters for functional imaging are the T1 and T2* relaxation values of the probe which is to be examined. Here a new method for the simultaneous measurement of T1 and T2* maps is presented. This method is robust against variations in flip angles due to B1 inhomogeneities of the resonator. Moreover, this sequence is time efficient because both parameters can be measured in the time the T1 measurement would take. Another advantage is that there no misregistration artifacts due to motion during a consecutive measurement of the single parameters T1 and T2*.

Material and Methods: Compared to a saturation recovery approach, the dynamic range of the inversion recovery method is approximately two times larger, which improves the fitting accuracy when computing T1 maps. A disadvantage of the inversion recovery experiment is that one must wait for the signal to completely relax to its thermal equilibrium before the next inversion pulse can be applied. T2* maps can quickly be obtained using a multi-gradient-echo sequence. However, especially when observing long T2* values this method becomes prone to accumulating gradient imperfections such as eddy currents, inaccurate preemphasis settings of the gradient amplifiers, and thermal variations due to the heating of the gradient system. One method to circumvent these problems is to use single echo acquisition with increasing echo times, which is time-consuming and can lead to misregistration artifacts of the successive single measurements. The method introduced here uses an inversion recovery snapshot FLASH sequence [1] including a T2* measurement using single echo acquisition with exponentially increasing echo times. The exponential increase is adjusted such that nearly the complete dynamic range of the inversion recovery curve is used. During the steady state tail of the T1 signal, the echo time is rapidly increased which allows the calculation of T2* values (Figure 1,2). Since the consecutive excitation pulses of the single FLASH sequences are no longer equidistant and thus the signal does not reach a steady state, the equations introduced by Deichmann [1] do not apply for this model. We therefore implemented a fitting algorithm which simulates the pulse sequence and calculates the resulting signal of this sequence. This allows us to fit the parameters M0, T1, and T2* by minimizing the mean square error of the measured data and the simulated signal. Other methods which measure T1 and T2* in one shot need to calculate flip angle maps in order to compute these relaxation parameters. Our model delivers correct values without adjusting the pulse angles over a large range. Simulations for a 6 degree excitation pulse showed that an increase of the flip angle of 50% causes an error in T1 of +0.72% and in T2* of + 0.92% and a decrease of the flip angle of 50% causes an error in T1 of -0.45% and in T2* of -0.55%. These errors are negligible compared to the errors caused by noise.

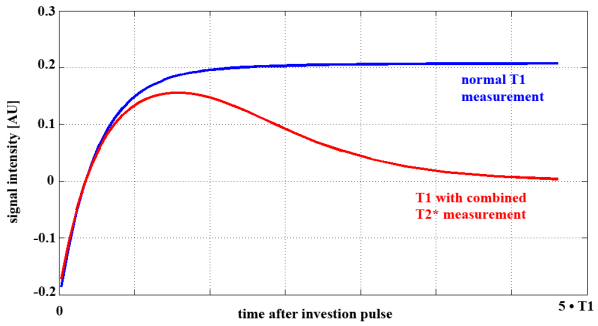

Figure 1: *Signal evolution of a standard inversion recovery experiment (blue) compared to the signal evolution of the presented combined T1/T2* measurement (red).*

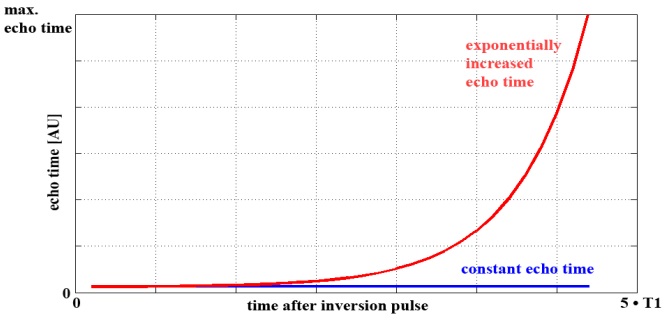

Figure 2: *Echo time of the standard inversion recovery experiment (blue) compared to the echo time of the combined T1/T2* measurement (red) which are shown in Figure 1.*

Results: Figure 3 depicts the measured data and the corresponding fit of one typical pixel using the combined T1/T2* measurement of a Magnevist-doped water phantom. The diagram demonstrates that the fitting model simulating the pulse sequence describes the data very well. In Table 1, the values derived from the single parameter measurements are compared with the values obtained from the combined T1/T2* method. The small errors of average 0.55% and 3.30% for the T1 and T2* measurements, respectively, confirm that this method is suitable for the simultaneous measurement of these two relaxation parameters. The slightly higher error in the T2* measurement can be attributed to thermal variations of the gradient system since the single T2* measurement was performed using a multi gradient echo sequence which causes the system to heat.

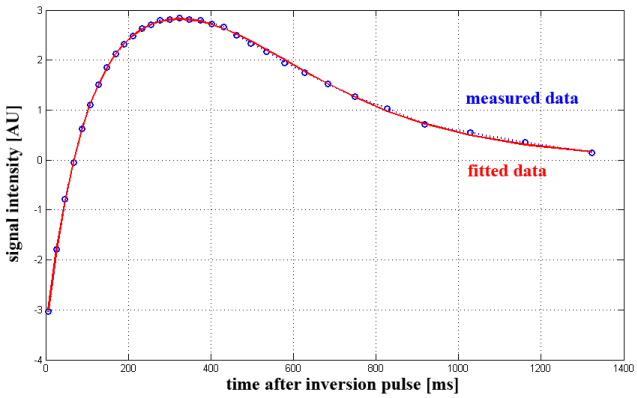

Figure 3: *Measured data (blue) and the corresponding fit (red) of one typical pixel of a Magnevist-doped water phantom.*

Probe	T1 single [ms]	T1 comb. [ms]	error [%]
1	97.01	97.55	0.55
2	90.18	90.98	0.88
3	91.70	91.50	0.22

Probe	T2s single [ms]	T2s comb. [ms]	error [%]
1	42.42	44.94	5.94
2	48.90	50.33	2.92
3	49.00	49.50	1.02

Table 1: *T1 and T2* values of a ROI of different phantoms measured using a normal inversion recovery method (T1 single), a multi gradient echo sequence (T2* single), and the combined T1/T2* method (T1 comb. and T2* comb.).*

Conclusion: In this study, a robust method for the simultaneous measurement of T1 and T2* maps was developed. The applicability of this sequence was confirmed using measurements on several phantoms and in vivo (data not shown). This method allows for the acquisition of T1 and T2* in the time a single T1 measurement would take. In future work, this method will be adapted to in vivo measurements of mice allowing a simultaneous measurement of the BOLD effect and perfusion using spin labeling methods.

References: [1] Deichmann R et. al. JMR 1992, 96:608-612; [2] Warntjes J.B.M et. al. MRM 2007, 57:528-537