Measuring and Imaging T2 without Echoes?

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Introduction. T_2 is nearly always determined by the spin-echo (SE) method. Here we present a new approach to measuring T_2 without echoes, utilizing the fact that long-duration adiabatic excitation pulses are prone to T_2 decay during excitation [1]. We measure T_2 by recording the ratio of MR signals acquired with and without long-duration adiabatic pulses. T_2-imaging is performed by incorporating a long-duration adiabatic pre-pulse in the MRI sequence. Use of 0° adiabatic BIR4 [2] pre-pulses ensures that other contrast properties of the MRI sequence are unaffected. The method is validated on phantoms by comparison with the SE method.

Theory. After a long θ° BIR4 adiabatic pulse, the magnetization is attenuated by a factor, $E_p(T_2,\tau, B_1,f_{max})$, where τ is the pulse length, B_1 is the excitation field, and f_{max} is the frequency sweep of the adiabatic pulse. The steady-state transverse signal is [1]: $M_{xy}=[M_0(1-E_1)\sin\theta.E_p]/(1-\cos\theta.E_1.E_p)$ where $E_1=\exp(-T_R/T_1)$. Now consider two trains of 90° adiabatic pulses applied with the same T_R but different τ's, $\tau_1$and τ_2. The ratio of the two steady-state signals, R_{T2}, versus T_2 is obtained from a numerical simulation of the Bloch equations, and plotted in Fig. 1 for B_1=20μT, f_{max}=15kHz, T_1=1s, τ_1=5ms and τ_2=35ms. Given R_{T2}, T_2 can be read from the graph. R_{T2} changes by ≤3% for different T_1 as long as T_1≥200ms.To determine the potential accuracy of the method, a *Monte-Carlo* simulation was performed. This showed that with 5% standard deviations (SD) in R_{T2}, the dual-τ method for these pulse lengths produced T_2 values with SD≤15% for T_2≤ 70ms.

Fig. 1: Ratio R_{T2} of dual-τ signals vs T_2

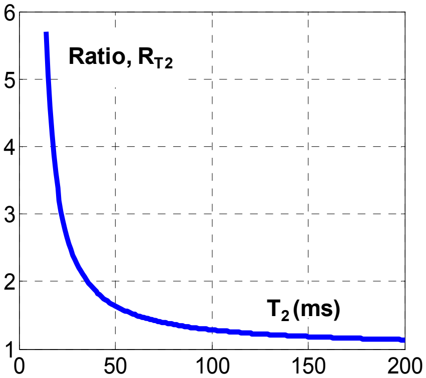


Fig. 2: Dual- τ vs SE T_2 on phantoms

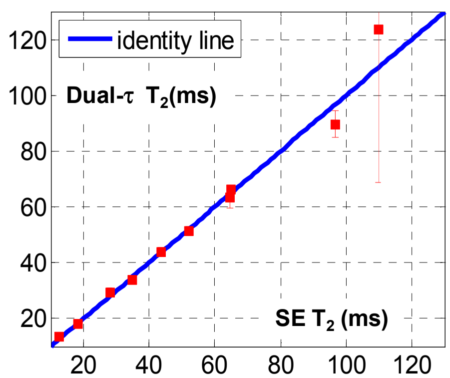
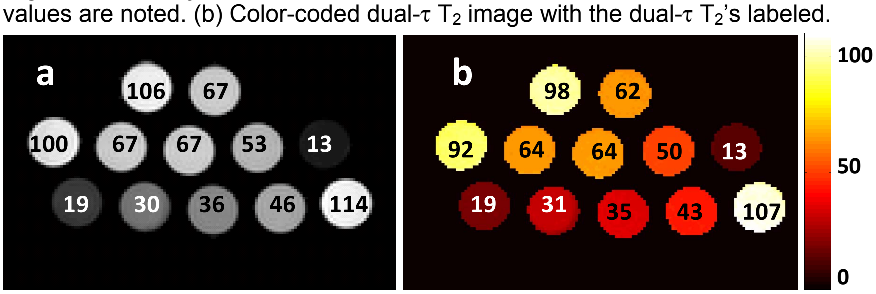


Fig. 3: (a) T_2-weighted MRI of phantoms (0° 35ms BIR4 pre-pulses). The SE T_2 values are noted. (b) Color-coded dual-τ T_2 image with the dual-τ T_2's labeled.



Methods. The dual-τ method was validated in $CuSO_4$-doped gel phantoms whose agarose concentrations were adjusted for 10ms ≤T_2≤110ms. T_1 and T_2 were first measured by standard partial saturation and SE NMR methods. Dual-τ T_2 was then measured with θ=90° BIR4 pulses [2], τ_1=5ms and τ_2=35ms.

Use of θ=0° BIR4 pre-pulses (τ_1=5, τ_2=35ms) for T_2-weighting was tested with standard slice-selective excitation for gradient-echo MRI to measure T_2 and provide T_2-weighted images. As the excitation pulses are unchanged and short, Fig. 1 is again used to obtain T_2.

Results. The T_2 measured by the dual-τ method is plotted vs. SE T_2 for the phantoms in Fig. 2. Measurements are accurate to ≤8% up to 100ms, after which accuracy deteriorates, as predicted. The θ=0° pre-pulse experiment performed similarly (Fig. 3). Images acquired with short- and long-τ adiabatic pre-pulses show T_2 weighting and T_2 images with values consistent with the SE T_2's of the phantom set (Fig. 3b).

Discussion. Adiabatic excitation pulses are self-refocusing and subject to T_2 decay when unduly long. These properties suit them for measuring T_2 without spin-echoes, at least in shorter T_2 regimes. The same property delivered with an otherwise neutral 0° flip-angle, can allow T_2-imaging, T_2-weighting or T_2-filtering.

1. El-Sharkawy, *et al*. Magn Reson Med 2009; 61:785-795. 2. Garwood M, *et al*. J Magn Reson 1991; 94: 511-525.
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