INTRODUCTION. T₁ and T₂ are typically determined by separate partial saturation (PS) or inversion recovery and spin-echo (SE) experiments. We propose a new method to measure both T₁ and T₂ in just three acquisitions, without using echoes or varying the repetition period T₉. Instead, T₂ is measured by varying the pulse length (τ) of an adiabatic B₁-independent rotation (BIR-4) pulse in two of the acquisitions, based on the fact that long adiabatic excitation pulses are prone to T₂ decay [1,2]. T₁ is determined by varying the flip-angle in two acquisitions, analogous to the dual-angle method [3]. Thus, this 3-acquisition “Tri-τ” method employs an α hard pulse excitation, a β short-duration BIR-4 pulse, and a β long-duration BIR4 excitation. The method is validated with T₁ and T₂ SE and PS measurements on phantoms.

THEORY. Because during BIR-4 pulses the magnetization spends time in the transverse plane and is subject to T₂, pulses and a third signal S₁ may be acquired with a (single) Tstraße to permit adequate T₁ attenuation and resolution. Thus the Tri-τ method acquires: a first signal S₁ with a conventional short (τ<<T₂) RF excitation pulse; a second signal S₂ with a β BIR-4 pulse of duration T₂; and a third signal S₃ with a β BIR-4 pulse of length T₁ = 2T₂. With E₁ = exp(-T₁/T₁), the three steady-state signals are: S₁ = [M₀(1−E₁)sinα] / (1−E₁cosα); S₂ = [M₀(1−E₁)E₂pβsinβ] / (1−cosβE₂p) [3]; S₃ = [M₀(1−E₁)E₃pβsinβ] / (1−cosβE₃p) with Eₓᵧ and Eᵧ as the transverse and longitudinal attenuation factors. From numerical simulations with practical BIR-4 pulses and β<80°, Eₓᵧ = Eᵧ = E_p = exp(−g·τ/T₂); E₃p = (E₂p)², and the equation set simplifies to a quadratic with solutions of E₂p and E₁, yielding T₁ = -Tp / ln(E₁) and T₂ = -(g·τ) / ln(E₂p), where g is a constant reflecting the time spent by the magnetization in the transverse plane.

METHODS. Numerical simulations based on the Bloch equations were performed with B₁=20µT, fmax=15kHz at 3T. BIR-4 pulse lengths were varied over 5≤τ≤40ms to determine g as a function of T₁, T₂ and flip-angle. Monte-Carlo simulations were performed to determine the accuracy of the Tri-τ method at signal-to-noise ratio (SNR)=50, with experimental values of T₁=2T₂=20ms, T₁=0.3s.

The Tri-τ method was validated experimentally in ¹H NMR studies of 6 CuSO₄-doped gel phantoms on a Philips 3T Achieva scanner with 219sT₁≤890ms and 31≤T₂≤129ms, as determined by standard SE and PS methods. S₁ was acquired with α=15° 75µs hard pulse, S₂ and S₃ are excited by 60° BIR4 pulses.

RESULTS. The Bloch simulations yielded g=0.81 for T₁=1s, 14≤T₂≤120ms and θ<80°, varying less than 1.5% for 120≤T₁≤1000ms. The Monte Carlo simulations of the Tri-τ method showed that T₂ could be measured with a mean error of -10% to 2% for T₂≤80ms and 0.1≤T₁≤1s (Fig 1). The error in T₁ was ±1%±15%(SD) for 0.3≤T₁≤1s, 30≤T₂≤130ms (Fig 2).

T₂ and T₁ values measured from the Tri-τ experiments on phantoms are compared with SE and PS T₁ and T₂ values in Figs 3, 4. The results show good agreement for all phantoms.

DISCUSSION. Because the proton density derives directly from the fully-relaxed signal, the Tri-τ method offers the potential for obtaining all of the T₁, T₂ and signal density information with just three acquisitions—arguably the minimum possible. The caveat is that the method requires accurate setting and knowledge of the flip-angles. This new method can potentially save time and simplify relaxation measurements. Extension of the approach to MRI is currently underway.