

Value of Independent Flip Angle Mapping for Transverse Relaxometry with Stimulated Echo Compensation

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INTRODUCTION: Stimulated echo compensation [1] enables standard multi-echo spin echo sequences to be used for accurate single component T2 quantification by accounting for slice profile and both stimulated and spin echo pathways. This method produces both a T2 map and a relative flip angle map. However, for a given T2 decay, two solutions exist with refocusing angles above and below 180°, with potentially different T2 values. Therefore, the flip angle (FA) solution is typically constrained to refocusing angles of 180° or less. Including prior knowledge from an independent FA map eliminates one fitting parameter, and the need to constrain FA solutions. However an independent FA determination is not always available, takes additional time, and typically has different slice profiles than those used in multi-echo spin echo relaxometry. *The purpose of this work is to evaluate the flip angle constraint on stimulated echo compensation and determine the value of an independently measured FA map for transverse relaxometry using a multi-echo spin echo acquisition.*

METHODS: Computer simulations and human brain imaging experiments were performed using stimulated echo compensation for T2 fitting. The method was performed with and without prior FA input. Decay curves were simulated for a wide range of T2 values (20-1000 ms), refocusing flip angles (100 – 260°), and slice profile widths (nominal: Gaussian pulses with refocusing pulse 1.75 times thicker than the excitation width). These simulated curves were then fit for T2 using the original stimulated echo compensation [1], or a modified version with input of independent FA map. Simulations were also used to assess the sensitivity of the T2 fit to errors in the FA map.

Human brain imaging experiments were performed at 4.7 T. Axial, single slice multi-echo spin echo images were acquired through iron-rich deep grey matter with TR = 3 s; TE = 10 to 320 ms; echo spacing = 10 ms; prescribed excitation = 90°; refocusing = 180°; matrix = 256 x 145; voxel size = 1 x 1.25 x 4 mm³. The experiments were repeated with different RF power levels to vary the effective flip angles. In each case, FA maps were acquired using a standard double angle method [2] with a correction for slice profile, with geometry and pulse shapes matched to multi-echo data (TR = 7 s; FA = 60°, 120°; TE = 43 ms). Normalized FA (nFA) maps are expressed as a ratio of the flip angle relative to the requested flip angle: $\alpha/\alpha_{\text{requested}}$.

RESULTS: Simulation results indicate identical decay curves with refocusing angles of 144° (nFA = 0.8) and 216° (nFA = 1.2) when non-selective pulses are employed (Fig 1a). The use of slice-selective pulses eliminates this degeneracy between high and low FA environments. Different decay curves at high and low FA will result in erroneous T2 maps with the original stimulated echo compensated fitting (Fig 2) which constrains nFA to less than or equal to 1.0. When an independent FA map is available, Fig 4 shows the T2 error that arises from errors in the FA map, illustrating a tolerance to mild FA error in most cases. Human brain data with FA purposely greater than 1 are shown in Fig 3. Note the differing FA maps found, but corresponding R2 maps are very similar, with or without independent FA. However, a small underestimate of T2 (typically < 3% for this conservative relative refocusing width of 1.75) is found relative to the original program in areas of nFA > 1, as predicted by theory (Fig. 2b). This error increases for narrower relative refocusing widths (2a), as needed for continuous multi-slice coverage. Error decreases for wider refocusing widths (2c), which are impractical for most 2D multi-slice applications.

CONCLUSIONS: If available, an independent and accurate FA map can improve T2 fitting with stimulated echo compensation in regions where the refocusing flip angle is greater than 180° and 2D slice selection is used.

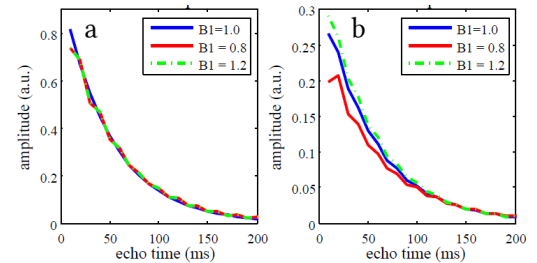


Fig 1: Decay curves for T2=50 ms for different normalized flip angles (B1=0.8,1.0,1.2) for (a) non-selective and (b) 2D selective pulses.

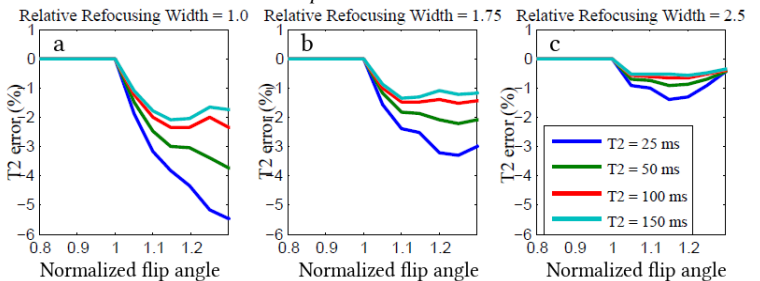


Fig 2: Error in T2 fitting with original stimulated echo compensation for a range of flip angles and different relative refocusing widths of (a) 1.0, (b) 1.75, and (c) 2.5.

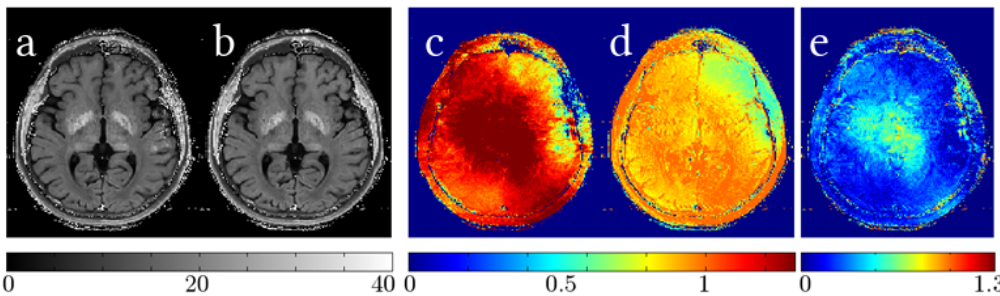


Fig 3: (a-b) $1/T_2$ maps (1/s) and corresponding normalized flip angle maps, where (a,c) FA is input or (b,d) simultaneously fit, (e) difference between FA methods.

REFERENCES: 1. Lebel RM, Wilman AH. Transverse relaxometry with stimulated echo compensation. *Magn Reson Med.* 2010;64:1005–14. 2. Stollberger R, Wach P. Imaging of the active B1 field in vivo. *Magn Reson Med.* 1996;35:246–51.

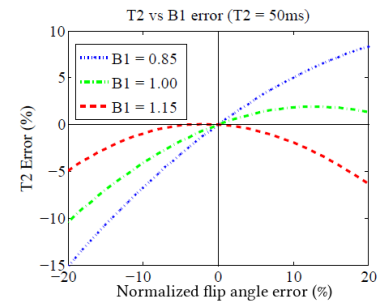


Fig 4: T2 error when provided with an incorrect FA input using T2 of 50 ms and three nFA values (B1=0.85, 1.0, 1.15).