Optimal Flip Angle Set in Spoiled Gradient-Echo MR Imaging Technique

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Introduction: In dynmiac contrast enchanted-MRI (DCE-MRI), T_1-Weghited spoiled Gradient-Echo (SPGR) sequences are utilized to monitor the distribution of the paramagnetically labeled CAs (contrast agent) in cerebral tumors due to high temporal and spatial resolution [1]. The tissue concentration of CAs measured by CAs effects on the longitudinal relaxation rate of water protons R_1 is used by tracer kinetic modeling [2]. In spoiled gradient echo sequences, the T_1-weighting of image contrast is strongly affected by a nonlinear interaction of two sequence parameters, repetition time (TR) and flip angle (α) [3]. The optimal TR and α are chosen to produce the field-dependent contrast behavior in MRI imaging, because the longitudinal relaxation time T_1 is field dependent [4]. However, the variation of signal to noise ratio (SNR) directly affects on the accuracy of the various quantitative methods and consequently introduces bias in estimation of MR and physiological parameters. Therefore, a pulse sequence with a set of flip angels which provides a best signal to noise ratio would be useful in various quantitative methods. In this study, a set of optimal flip angles that are necessary to provide better tissue contrast at different magnetic field strengths (3T, 7T) is determined.

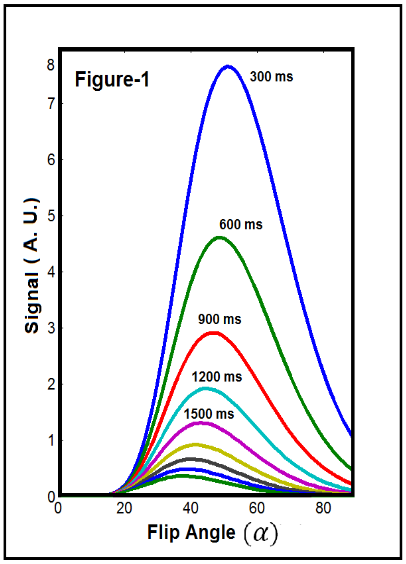
Materials and Methods: The SPGRE signal based on the Bloch equation for T_1 relaxation time is given by [3] equation-1. Where S_0 denotes the equilibrium longitudinal magnetization. Equation-1 can be rewritten as a linear form to compute the longitudinal relaxation time (T_1) for given TR and α as [4].This shows that the signal contrast is a function of both TR and flip angle. A set of optimal flip angels

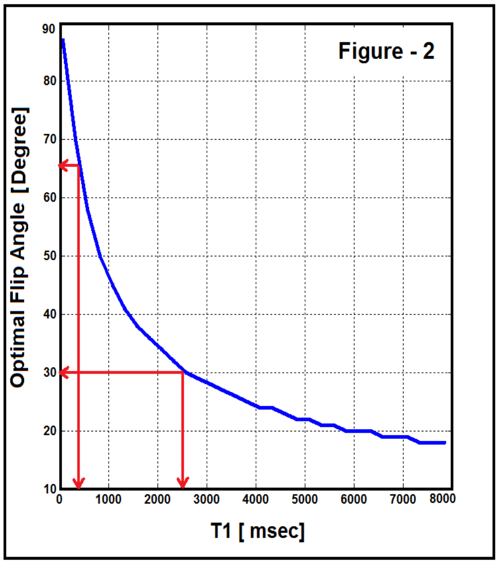
$$S(\alpha) = S_0 \frac{\left(1 - e^{\frac{-TR}{T1}}\right) Sin(\alpha)}{\left(1 - \cos(\alpha) e^{-\frac{TR}{T1}}\right)} \quad (1)$$

$$\frac{S(\alpha)}{\mathrm{Sin}(\alpha)} = \frac{S(\alpha) e^{-\frac{TR}{T1}}}{\tan(\alpha)} + S_0\left(1 - e^{-\frac{TR}{T1}}\right) \quad (2)$$

for a given TR (~6ms) was determined by varying the longitudinal relaxation time (T_1) over the observable range of brain tissue [200ms-2500 ms] at various field strengths (3T/7T). The SPGR signal evolved from the brain tissue was simulated using Equation 2 as in the experimental condition. The equilibrium magnetization calculated at the end of the each acquisition cycle served as the initial magnetization for the next cycle. The amplitude of the signal at the steady state condition (i.e. at asymptotic region) was used as the measure of signal in each experiment. The simulation was repeated for different range of flip angles. The flip angle which produces maximum signal was considered as the optimal flip angle for the given longitudinal relaxation time (T_1).

Results and Discussion: Figure-1 shows the calculated signal as a function of the flip angle for various longitudinal relaxation times T_1 based on the SPGR sequence. The plot demonstrates that flip angle dramatically changes the signal intensity, in which a peak of the curve shifts towards a lower region of a flip angle. In Figure-2 the optimal flip angle is plotted as function of the longitudinal T_1 relaxation time and shows the range of the optimal angle required for the field strengths (≥ 3T). The SPGR imaging is a time efficient method of T_1 weighted imaging in the brain. Therefore, this study focuses on the computation of the optimal flip angles which are required to minimize the calculation error of static T_1 values during MR acquisitions. Thus the optimal angles helps to keep the signal to noise ratio more efficient and more accurate, in which the repetition time TR held constant [4].Therefore, this study suggests optimal set of flip angles between 30 to 65 degrees for 3T system and 30 to 45 for 7T.





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