Analysis of Saturated T_2 Curves for Rapid Relaxometry Measurements in PRESS Localization

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Introduction

The ***R**apid **R**elaxometry through **A**cquisition of **M**ultiple **S**aturated T_2 **C**urves* (RRAMSC) technique is a fast method for collecting data for compartmental analysis for *in vivo* single-voxel ^{1}H MRS *(1,2)*. The technique allows high density sampling of relaxation curves for simultaneous calculation of T_1, T_2, and separation of the tissue water and cerebral spinal fluid water signal contributions, *within 90 seconds*. RRAMSC has been shown to replicate results of the standard long TR T_2 experiment with equal or better precision *(1)*. The primary drawback of RRAMSC is that, in theory, it is only compatible with the stimulated-echo based localization technique, where the magnetization recovery is well-defined *(2)*. In this analysis, we examine the theory of employing RRAMSC with the widely-used PRESS localization technique.

Theory

In the stimulated echo localization sequence, the degree of signal T_1 saturation is controlled by one time interval, the recovery period TD, defined as TR-TM-TE/2 (Eq. 1). Thus any changes in the TE can be offset by changes in TR to keep saturation losses constant.

$$S(TE,TM,TR) = S_O \exp\left(-\frac{TE}{T_2}\right)\left[1-\exp\left(-\frac{TR-TM-TE/2}{T_1}\right)\right] \quad (1)$$

For the PRESS sequence, there is no such single time interval (Eq. 2); thus, the necessary tradeoffs between TE and TR – to keep saturation losses constant - are not easily determined and will depend on the specific T_1 of each species.

$$S(TE,TR) = S_O \exp\left(-\frac{TE}{T_2}\right)\underbrace{\left[1-2\exp\left(-\frac{TR-3TE/4}{T_1}\right)+2\exp\left(-\frac{TR-TE/4}{T_1}\right)-\exp\left(-\frac{TR}{T_1}\right)\right]}_{\text{Saturation losses}} \quad (2)$$

However, a tedious but straightforward power series expansion of Eq. 2 shows that it can be approximated by

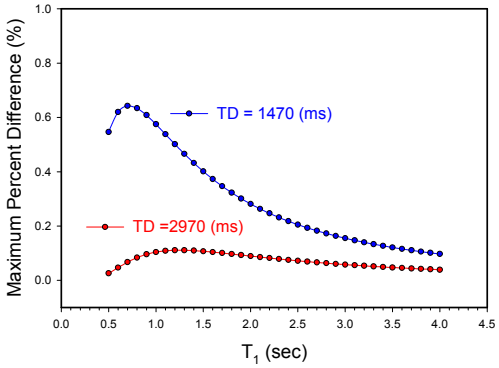
$$S(TE,TR) \approx S_O \exp\left(-\frac{TE}{T_2}\right)\underbrace{\left[1-\exp\left(-\frac{TR-TE}{T_1}\right)\right]}_{\text{Approximate saturation losses}} \quad (3)$$

where the TD is TR-TE for the PRESS sequence. The efficacy of this approximation can be validated by modeling saturation losses in Eq 2, based on TR/TE pairs generated to satisfy a constant TD in Eq. 3. Table I shows parameter selections for a 32-point (16 points per curve) RRAMSC collection of two saturated curves for PRESS, where the initial TRs are 1.5 and 3.0s. T_1 saturation losses are calculated from Eq. 2 for all TE/TR pairs in Table I, for T_1 ranging from 500-ms to 4000-ms in 100-ms increments. The maximum signal percent difference, (high-low)/low x 100%, is calculated for each T_1 over the range of TEs in each set. Figure 1 simulations suggest that Eq. 3 is an excellent approximation for Eq. 2, as *all signal differences are less than 1%* for all T_1 values from 500-ms to 4000-ms.

Table I. RRAMSC Parameters for PRESS Simulation

TE	TR (TD=1.47s)	TR (TD=2.97 s)
30	1500	3000
38	1508	3008
48	1518	3018
60	1530	3030
76	1546	3046
97	1567	3067
122	1592	3092
154	1624	3124
195	1665	3165
246	1716	3216
311	1781	3281
393	1863	3363
496	1966	3466
627	2097	3597
792	2262	3762
1000	2470	3970

Figure 1. Simulated saturation variations in RRAMSC for PRESS localization sequence.



Discussion

RRAMSC was originally developed for compartmental analysis application for a stimulated-echo based localization sequence; however, as shown here, the technique may be applicable to the PRESS localization sequence as well. Simulations presented here suggest that while signal saturation losses cannot be made constant for PRESS, residual variations should be extremely minor (< 1%), particularly for long T_1 values, such as at higher field strengths or with cerebral spinal fluid. For the above example, with the addition of four preparatory cycles before each curve, the total acquisition time would be 98s. By sampling only 14 points per curve or slightly reducing the TD times, the acquisition time can be easily lowered to less than 90s. If T_1 and compartmental analysis is not desired, these simulations indicate that T_2 can be rapidly measured (< 30 sec) with a high sampling density using a saturated T_2 curve. Overall, the RRAMSC should be ideal for human high field studies, where the combination of long T_1 values and the necessity to keep experiment times short, may normally make relaxometry studies prohibitively long. .

Conclusions

We have demonstrated, in theory, that the RRAMSC technique should be applicable to PRESS, providing a rapid method for collecting localized compartmental analysis data.

References

(1) Knight-Scott et al., J Magn Reson 2005; 173:169-74. (2) Knight-Scott J. *Joint Annual Mtg ISMRM/ESMRM*, (Berlin, Germany, 2007) p 202