Maximizing the Hyperpolarized Signal for a T_1 Compensated Variable Angle Acquisition

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Introduction After the preparation of hyperpolarized compound the signal begins to decay at the T_1 relaxation rate. It is important to understand the best method for utilizing this signal. Since signal is reduced by both the T_1 and acquisition pulses an optimal scheme for acquiring signal is required to maximize signal-to-noise. Variable angle[1,2] hyperpolarized CSI imaging has been done previously to accommodate r.f. losses without any attempt to compensate for T_1 losses. We have expanded this to included losses from T_1 relaxation with scheme aimed at producing a quasi-steady state signal (Abstract #407 submitted).

Purpose To compare variable angle schemes to determine the optimal sampling to acquire the most signal.

Methods Five T_1 values (**∞**, 60, 30, 15 and 5 seconds) were theoretically examined for an acquisition total time of 60 seconds. The acquisition time was divided into twelve 5 second acquisition windows; a scheme that would be appropriate for CSI and imaging where temporal information about distribution and metabolism is sought. Each five second acquisition were composed of 16, 64 or 128 r.f. pulses. Two methods were compared. (**Method 1)** The first method was a variable pulse with T_1 compensation were n_{max} was equal to the total number of pulse for the entire 60 second acquisition. In this case, the expected signal should remain constant. n then ranges for 1 to (number of r.f. pulse X 12)

$$\theta[n] = \begin{cases} 90^\circ & \text{if } n = 1 \\ \arctan(\sin(\theta[n-1]))e^{-i/T_1} & \text{if } n > 1 \end{cases}$$

The second method **(Method 2)** sought to maximize the signal of each 5 second interval by determining the optimum signal that should remain after each 5 second interval for each T_1 value. The starting, ɵ[n+ r.f pulses] and ending ɵ[n] angles (the value of n determines the amount of signal remaining after the ɵ[n] pulse) were determined by maximizing the total signal of the 60 second interval for different remaining percentages after each five second acquisition window e.g. the total signal was summed with all 5 second acquisition windows having 70% of the signal remaining after five seconds and compared against a total sum of all 5 second acquisition windows having 80% of the signal remaining after five seconds.

Results For the values of T_1 less than 60 seconds, the second method proved to produce the highest combined signal over the entire 60 minute period. The method provided the greatest improvement with the lowest value of T_1. An equation was determined from the data to describe the correlation between the ratio, RSN, of the signal-to-noise between the methods, $RSN=0.861e^{4.31X}$ (R^2 = .992) (Figure 1) where X is the ratio of the individual image time to the T_1. The point where both methods produce similar signal quantity, R=1, is when the T_1 is 2.4 times the total acquisition time. Additionally, an equation can be fit to the data to determine the optimal signal to leave after each repetition time for the second method (Table 1),

% Signal Remaining = $94.8e^{-1.8X}$ (R^2=.997).

Discussion As T_1 becomes much larger than the total acquisition time, the second method has little advantage. The gains observed in the signal in the second method are due to acquiring a majority of the signal in the first imaging acquisition windows before the signal can decay rapidity via T_1 processes. In addition, the data obtained allowed for a determination of the optimal pulses required to balance signal loss by T_1 with signal reductions due to r.f. pulses. This method provides a way of determining how to maximize the signal-to-noise for imaging based on the *in vivo* T1 which is under investigation.

References:

(1) Zhao L., Mulkern R., Tseng C., Williamson D., Patz S., Kraft R., Walsworth R. L., Josesz F. A. and Albert M. S. *J Magn Reson B* **1996,** *113*, 179-83.
(2) Hu S., Lustig M., Chen A. P., Crane J., Kerr A., Kelly D. A. C., Hurd R., Kurhanewicz J., Helson S. J., Pauly J. M., and Vigneron D. B. *J Magn Resonance* **2008**, *192*, 258-64.

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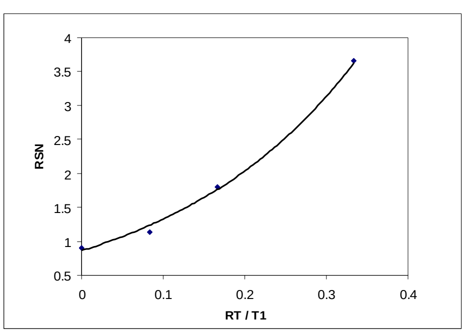

Figure 1: Ratio of the RSN of Method 2 to Method 1

T_1(sec)	RT/T_1 (X)	% Signal Remaining
∞	0	90
60	0.083	82
30	0.167	71
15	0.333	55
5	1	15.3

Table 1: Optimal Signal to leave based on the Repetition time (RT) and T_1