Maximizing the Hyperpolarized Signal for a T\textsubscript{1} Compensated Variable Angle Acquisition

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**Introduction**
After the preparation of hyperpolarized compound the signal begins to decay at the T\textsubscript{1} relaxation rate. It is important to understand the best method for utilizing this signal. Since signal is reduced by both the T\textsubscript{1} and acquisition pulses an optimal scheme for acquiring signal is required to maximize signal-to-noise. Variable angle\textsuperscript{1,2} hyperpolarized CSI imaging has been done previously to accommodate r.f. losses without any attempt to compensate for T\textsubscript{1} losses. We have expanded this to included losses from T\textsubscript{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\textsubscript{1} values (\infty, 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\textsubscript{1} compensation were \(n_{\text{max}}\) angles (the value of \(n\) determines the amount of signal remaining after the \(e[n]\) pulse) were determined by maximizing

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

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)

- 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\textsubscript{1} value.

\[
\text{% Signal Remaining} = 94.8e^{-1.8X} (R^2 = .979)
\]

**Results**
For the values of T\textsubscript{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\textsubscript{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\textsuperscript{4.91X} (\(R^2 = .992\)) (Figure 1) where X is the ratio of the individual image time to the T\textsubscript{1}. The point where both methods produce similar signal quantity, R=1, is when the T\textsubscript{1} is 2.4 times the total acquisition time.

**Discussion**
As T\textsubscript{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 rapidly via T\textsubscript{1} processes. In addition, the data obtained allowed for a determination of the optimal pulses required to balance signal loss by T\textsubscript{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 T\textsubscript{1} which is under investigation.

**References:**


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<table>
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<tr>
<th>T\textsubscript{1}(sec)</th>
<th>RT/T\textsubscript{1} (X)</th>
<th>% Signal Remaining</th>
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<tr>
<td>\infty</td>
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<td>90</td>
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<tr>
<td>60</td>
<td>0.083</td>
<td>82</td>
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**Figure 1:** Ratio of the RSN of Method 2 to Method 1