**Quantitative Measure of Magnetization Transfer:**

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**Introduction:**

Magnetization transfer (MT) is widely used in the evaluation of demyelinating diseases, including multiple sclerosis (MS). An easily obtained and commonly used measure of MT is the magnetization transfer ratio (MTR). However, the MTR is dependent on a variety of experimental and tissue parameters, making its physical interpretation in terms of specific disease processes (inflammation, demyelination, etc.) uncertain. As an alternative, we are proposing a simple analysis scheme for MT measurements that isolates MT effects from experimental (frequency offset and saturation pulse scheme) and tissue relaxation parameters (T1 and T2).

**Quantitative MT Parameter:**

The proposed method of analysis combines data from the standard MTR pulse sequence with estimates of tissue T1 and T2 relaxation time constants and RF saturation pulse characteristics. Calculations were based on the two-pool model's prediction of steady state longitudinal magnetization with CW irradiation [1]. Using Henkelman's approach [1] the MT parameter $RM_0^B$ can be expressed as:

$$RM_0^B = \frac{M_{SAT}(R_A + R_A R_{RFB} + R_A R + R_{RFA} + R_{RFA} R_{RFB} + R_{RFA}) - R_A(R_{RFB} + R + 1)}{1 - M_{SAT} - M_{SAT} R_{RFB}} \quad [1]$$

where:

$M_{SAT}$ is the normalized intensity of the MT weighted image, $R_A$ ($1/T1_A$) is the longitudinal rate constant for the liquid pool, R is the exchange rate between the liquid and semisolid proton pools, and $R_{RFA}$ and $R_{RFB}$ are rates associated with the loss of longitudinal magnetization in the presence of off-resonance irradiation.

All of the above parameters can be easily evaluated, with the exception of the MT exchange rate R. However, it has been demonstrated [2] that R is constant for a given tissue and independent of demyelination and inflammation. For white matter R=21$\pm$2 $s^{-1}$. Saturation rates $R_{RFB}$ and $R_{RFA}$ can be calculated using estimates of saturation pulse amplitude, $\omega_1$ and offset frequency, $\Delta$. They also depend on T2 relaxation time constants and pool lineshapes. In the case of the liquid pool, T2 relaxation can be measured and the lineshape is Lorentzian. For the semisolid pool, the Super-Lorentzian lineshape and T2 relaxation, $T2_B$, are similar for most tissues [3] and much like R, are disease independent. $M_{SAT}$ can be evaluated by calculating the ratio of image intensities with and without the application of off-resonance RF saturation pulses.

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**Discussion:**

Quantitative MT parameter, $RM_0^B$, defined by equation [1] ,is independent of T1 and T2 relaxation and experimental parameters $\Delta$ and $\omega_1$. It also linearly scales with macromolecular MT content, $M_{OB}$, a measure which is typically correlated with myelination in white matter. Therefore, $RM_0^B$ represents a quantitative MT parameter that is independent of the MRI system used (i.e. 1.5 T *vs* 3 T) and provides a unique measure of white matter integrity.

In order to accurately determine $RM_0^B$ it is necessary to measure T1 and T2 relaxation times as well as $\Delta$ and $\omega_1$. It also requires *a priori* knowledge about R and $T2_B$. With these estimates and assumptions, all parameters can be typically determined to within 5% accuracy. Figure 1 shows $RM_0^B$ stability in the case of overestimating any one of the above parameters. Even with 5-10% error in parameter estimation, $RM_0^B$ is still within 10% of its actual value.

**Conclusion:**

We present a parameter that is equally easy to measure as MTR but has a more physical interpretation and is much more useful for data comparison when different MT techniques are used. With the estimates of T1, T2 and $\omega_1$ and the average literature values of R and $T2_B$ for white matter we can obtain a value for $RM_0^B$. Although, it is not a physical parameter (due to estimations), the value obtained scales with $M0_B$, the bound pool fraction, and is no longer dependent on experimental parameters.

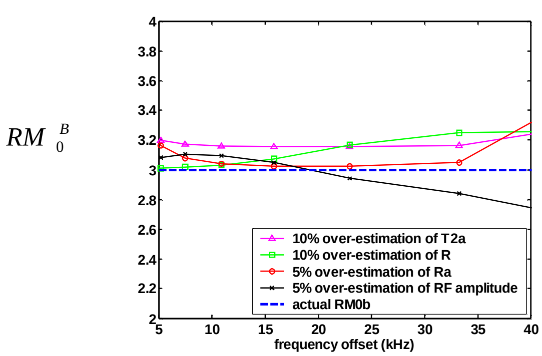


**Figure 1:** Even with errors in parameter estimation, the value of $RM_0^B$ is relatively constant over offset frequencies of 5-40 kHz (where the bulk of the MT effect occurs) and is within 10% of the correct value

**References:**

1 Henkelman et al, MRM 29 (6), 759-766 (1993)
2. Stanisz GJ et al, MRM 51 (3): 473-479 (2004)
3. Li J et al, MRM, 36, 866-871 (1997)