In Vivo Analysis of K^{trans} Repeatability of Signal Difference and Standard Concentration-Based Methodologies

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Introduction: Dynamic contrast enhanced (DCE) MRI has demonstrated to be a useful tool in evaluating tumor perfusion. The traditional means of evaluating perfusion is to first calculate the concentration time-course of an injected contrast agent (CA) from the change in the MR signal intensity, and subsequently estimate the perfusion parameters of the target tissue via the Kety model [1]. However, the accuracy of the computed perfusion parameters depends on the accuracy of intrinsic tumor T_1 measurements, as well as the knowledge of the true flip angles at the locations of the tumor and blood. Recently, an alternative strategy for perfusion parameters evaluation was introduced [2-3]. This method relies on an approximation of the Bloch equations, and it can be shown that the signal difference, or the MR signal itself with the baseline signal subtracted, is almost linearly proportional to the CA concentration [3]. Thus, the measured signal could be used for the model fitting without the need to convert to CA concentration. In this work, we compare the repeatability of the signal difference method with that of the conventional method in a test-retest study in a cohort of patients with lung tumors.

Methods: Under the assumption of TR<<T1, it has been shown that the signal differences are proportional to CA concentrations in tumor and blood:

$$\Delta S_t \propto C_t \qquad \Delta S_b \propto C_b \qquad (1)$$

where C_t and C_b are the CA concentrations, and ΔS_t and ΔS_b are signal changes (relative to pre-contrast baseline signal) in tumor and blood, respectively. As a result of this approximation, the signal difference can be used in place of concentration in the Kety model to derive the perfusion parameters more directly without the need for T_1 or flip angle measurements.

Prior to treatment, eighteen lung tumor patients were each scanned twice on average two days apart on a 1.5 T Siemens Sonata MRI scanner. 3D DCE-MRI with hybrid radial acquisition scheme and dynamic KWIC reconstruction were utilized [4]. Scan parameters were as follows: coronal FOV=300mm, slice thickness=8mm, 192×192 square pixels, TR=3.38ms, TE=1.6ms, flip angle 25° and 32 slices with 80% partial Fourier encoding. Bolus injection of 0.07mmol/kg Gd (Multihance) was administered at 1 cc/sec, two minutes after scanning began, followed by a 20 cc saline flush. Both conventional CA concentration-based and signal difference methods were used to obtain K^{trans} on a pixel-by-pixel basis. For the standard method, baseline correction was applied in order to enhance measurement accuracy [5]. Scatter plots and Bland Altman analysis were used to compare the repeatability of the two strategies.

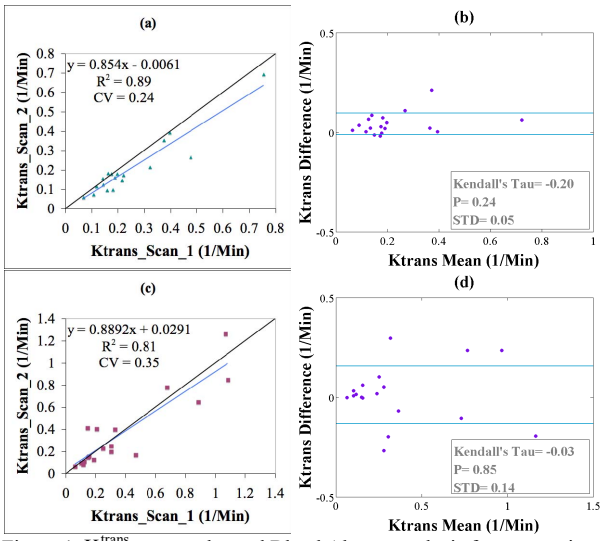

Figure 1. K^{trans} scatter plot and Bland Altman analysis for conventional (top row) and signal difference methods (bottom row).

Results and Discussion: Figure 1 shows the results of the comparison study. Overall, both the standard and the signal difference methods show good repeatability, with the former method performing slightly better: R^2 = 0.89 and 0.81 and coefficient of variation (CV) = 24 and 35%, respectively. The CV's observed here are similar to those found in the literature [6-7]. One interesting point to note is that the K^{trans} values calculated with the signal difference method is higher than the standard method, which is due to the fact that relationship between signal difference and concentration is not strictly linear as Eq. 1 indicates, and can lead to overestimation when the flip angle used for DCE-MRI is low. Such bias can be reduced when higher flip angles are utilized [8]. Finally, the Bland Altman plots show that there is no significant bias in the repeated measurements. It should be pointed out that since absolute signal intensities are used in the signal difference method, coil sensitivity information would be needed to normalize tissue signals at different locations. Since sensitivity maps were not available for this study, we could not take this into consideration, which may have also contributed to the lower repeatability of the signal difference method.

Conclusion: In this work, the standard concentration-based method of computing perfusion parameters is compared with a simpler signal difference method in patients with lung tumors using a 3D radial DCE-MRI sequence. Repeatability of K^{trans} is somewhat higher in the standard method, and is similar to those observed in previous studies using Cartesian based sequences. The results indicate that even in the absence of intrinsic T_1 or accurate flip angle information perfusion parameters can still be determined using the signal difference methodology, although it incurs a small penalty in measurement precision.

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References: (1) P. L. Choyke et al. JMRI. 17:509-520(2003). (2) E. Ashton et al. ISMRM 2007. (3) S. Walker-Samuel et al. Phys. Med. Biol. 52 (2007) 589-601. (4) W. Lin et al. MRM 60:1135-1146 (2009). (5) Y. Xue et al. ISMRM 2011; 1093. (6) S. M. Galbraith et al. NMR Biomed 15(2): 132-142 (2002). (7) K. J. Lankester et al. Br J Cancer 93(9): 979-985 (2005). (8) H. K. Song et al, ISMRM 2011; 1072.