Relative Changes in Tumor Perfusion (Ktrans, ve) is Independent of Absolute Baseline T1 Values

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Introduction

Dynamic Contrast-Enhanced (DCE) MRI is becoming an important tool in assessing the efficacy of new cancer therapies. In DCE-MRI, the baseline (pre-contrast) T_1 value of the tumor is required in order to accurately determine the perfusion parameter K^{trans} (first order rate constant). The multiple-flip angle method is often used to measure T_1 [1], but its accuracy is highly dependent on the accuracy of the flip angles, which are affected by B_1 homogeneity throughout the FOV and the excitation profile in 2D imaging.

Recently, it was shown that the relative change in the simple perfusion parameter IAUGC (initial area under the gadolinium contrast curve) pre- and post-treatment is independent of the actual baseline T_1 [2]. In this abstract, using both simulations and in vivo study, we investigate whether similar T_1-independence exists for the perfusion parameters K^{trans} and v_e.

Methods

A normalized ratio of a parameter is defined as

$$NRatio = \frac{P^{pre} - P^{post}}{P^{pre}} \qquad (1)$$

where P represents perfusion parameters (K^{trans} and v_e), and superscripts represent pre- and post-treatment.

For the simulation experiment, an arterial input function (AIF) was created according to the experimentally-derived functional form [3]. The tissue enhancement curves (TEC) were then derived based on Tofts' two-compartment model [4]:

$$C_t(t) = v_p C_p(t) + K^{trans} C_p(t) \otimes e^{-\frac{K^{trans} t}{v_e}} \qquad (2)$$

where C_p is the tracer concentration in the blood plasma; v_p is the blood plasma volume; K^{trans} is the volume transfer constant between the plasma and tissue; v_e is the volume of the extravascular extracellular space; and $\otimes$ represents a convolution. Three pairs of K^{trans} and v_e values for pre- and post-treatment were investigated. As done previously [2], it was assumed that baseline tumor T_1s were the same for pre- and post-treatment. NRatios were computed for a large range of T_1 values assuming true baseline T_1s of 300, 500, 800 and 1000.

For the in vivo study, DCE-MRI was performed on a patient with metastatic colon cancer to the liver using a fast 3D gradient-echo acquisition. The protocol is as follows: 16 slices with 80% partial Fourier encoding along k_z, FOV = 38x38 cm^2; slice thickness = 5mm; TE/TR = 1.6/3.2ms; receiver bandwidth = 550Hz/pixel; xres/yres = 256/128. GRAPPA parallel technique was employed for a 2x scan time reduction. The same protocol was run again after the treatment with anti-vascular drug treatment (Avastin) in combination with cytotoxic therapy (FOLFOX).

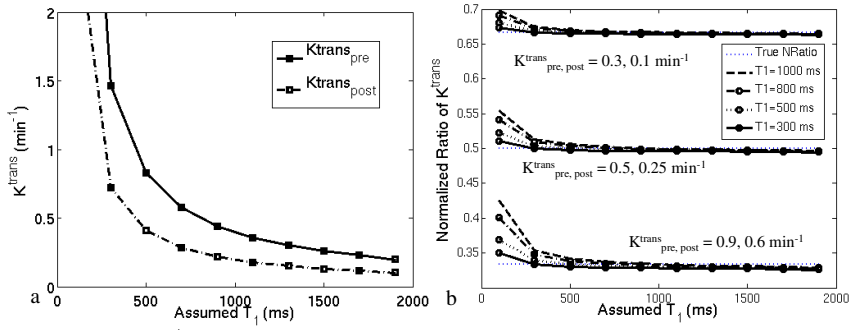

Fig. 1 (a) Plot of K^{trans} vs. T_1 for pre- and post-treatment when the true T_1=800 ms. (b) Plot of the normalized ratios of K^{trans} for true T_1 = 300, 500, 800 and 1000 ms for three pairs of pre- and post-treatment K^{trans} values.

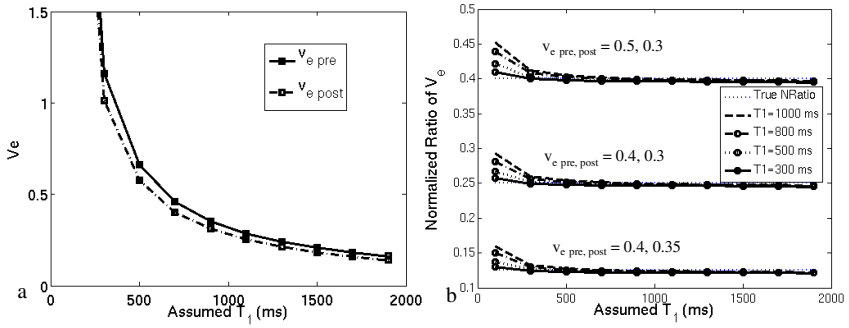

Fig. 2 (a) Plot of v_e vs. assumed T_1 for pre- and post-treatment for true T_1=800 ms. (b) Plot of the normalized ratios of v_e for true T_1 = 300, 500, 800 and 1000 ms for three pairs of pre- and post-treatment v_e.

Results

Figure 1a shows a plot of the computed K^{trans} as a function of assumed T_1 values for pre- and post-treatment. Figure 1b shows plots of the normalized ratio of K^{trans} as a function of the assumed T_1, for various true T_1values. The variation in the normalized ratio is less than 2% when the actual tumor T_1 ranges from 300 to 1900 ms. Figure 2 shows the results for v_e. Again, the variation in the normalized ratio of v_e is very small except when the assumed T_1 is 100 ms or less. Figure 3 shows the results from the in vivo study, showing plots of the normalized ratio of K^{trans} and v_e for various assumed T_1 values from 100 to 1900 ms. The normalized ratio of K^{trans} and v_e are very stable, and the results are consistent with simulation results.

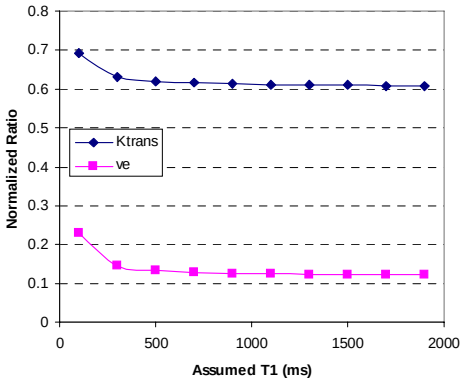

Fig. 3 Plot of the normalized ratio of K^{trans} and v_e in the vivo study.

Discussion and Conclusion

Uncertainties in the baseline T_1 of tumor tissue can lead to large variations in the measured K^{trans} and v_e as shown in Fig. 1a and 2a. However, our results demonstrate that the normalized ratio is insensitive to a large range of assumed T_1. Therefore, if the primary criterion for assessing drug effectiveness with DCE-MRI is the relative change in tumor perfusion, accurate baseline T_1 measurements may not be required.

Reference

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