Can Model Weighting Improve the Accuracy of DCE-MRI Parameter Estimation?

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TARGET AUDIENCE Basic and clinical scientists who use dynamic contrast-enhanced MRI

PURPOSE Many pharmacokinetic models have been proposed for analyzing dynamic contrast-enhanced MRI data [1]. However, it is difficult to obtain a *priori* knowledge of the underlying characteristics of a given tissue and, therefore, difficult to select which model is most appropriate for a study. To address this limitation, we have taken an approach from the meteorological literature [2] in which multiple models are weighted by a factor determined by how well they fit the data. Here, we analyze each voxel in a DCE-MRI data set with an array of models and use the Akaike Information Criteria (AIC; [3]) to determine the statistically optimal model. We reason that this approach provides a more unbiased approach to DCE-MRI than simply choosing one model for all regions of a tumor.

METHODS *Data Simulation* A 32 × 32 DCE-MRI image was simulated and divided into three equal sub-regions for DCE-MRI data generated with the Tofts-Kety model (TK), the extended TK model (ETK), and the shutter-speed model (SS). Gaussian noise was added to generate a range of data sets with SNR from 10 to 100. K^{trans} ranged from 0.01 min^{-1} to 1.56 min^{-1} in increments of 0.05 min^{-1} for each column of the 32 × 32 image. The v_e values were selected from 0.075 to 0.9 with an increment of 0.075 for each row in the sub-ROIs. The v_p and τ_i values were selected from 0.01 to 0.08 and from 0.1 to 1.0 in the ETK and SS regions, respectively. Other parameters included TR/α = 7.94 ms/20°, T_1 = 1.8 s, 97 dynamic time points with the temporal resolution of 4 s.

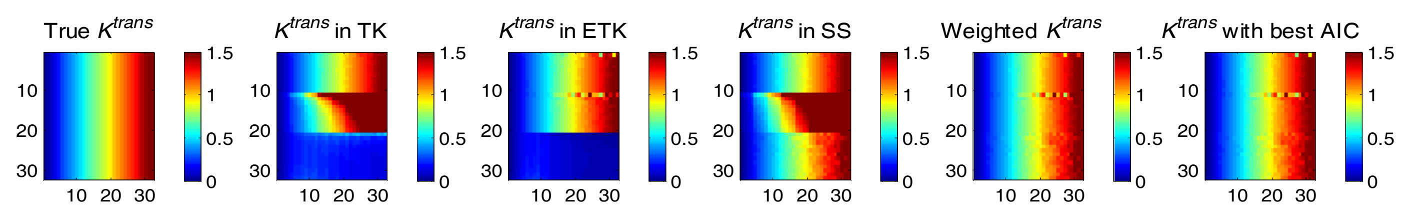

Fig 1. The figure displays the true K^{trans}, K^{trans} estimated from the TK, ETK, SS, weighted models, and with best AIC values for SNR of 30.

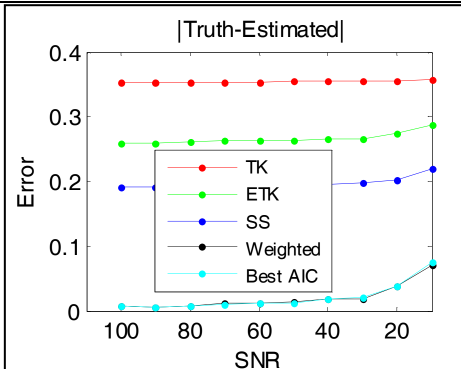

Fig 2. The mean errors between the truth and estimated K^{trans} for different SNRs.

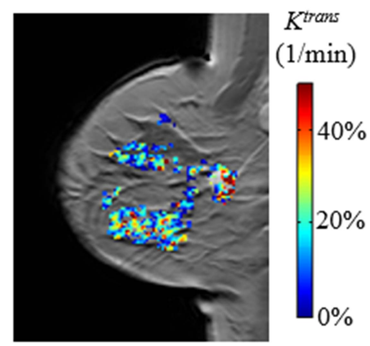

Fig 3. The K^{trans} %difference map between ETK and weighted models superimposed on the post-contrast DCE-MRI data for a pCR.

Data Analysis Each pixel was fit by all three models and the subsequent AIC values were calculated. The AIC weighted parameter was defined as: $p = \sum_{i=1}^{3} w_i * p_i$, where $w_i = \frac{\exp\left(-\frac{\delta_i}{2}\right)}{\sum_{j=1}^{3}\exp\left(-\frac{\delta_j}{2}\right)}$, $\delta_i = AIC_i - AIC_{min}$, p_i are the DCE-MRI parameters and AIC_i was the AIC values from the three models, respectively. AIC_{min} was the minimum AIC among the three models. A fifth approach simply selected the parameters with the best AIC.

RESULTS Figure 1 shows the true K^{trans}, and K^{trans} estimated from three models, from the weighted model, and from the model selecting the parameters with the best AICs for an SNR of 30, respectively. Figure 2 plots the errors between the true and estimated K^{trans} as a function of SNR. In a preliminary application to breast cancer data, we found four patients (out of 35) that were correctly re-classified as a responder or non-responder when using the model weighing approach, compared with the ETK model. One example is presented in Figure 3.

CONCLUSION The results show that the TK, ETK, and SS models yielded better results in their corresponding sub-regions but not in the other regions, while the weighted model estimated the parameters close to the true values throughout the whole ROI. Future work will investigate if the weighted approach outperforms individual models when, for example, predicting treatment response.

REFERENCES 1. Yankeelov TE et al. Curr Med Imaging Rev 2009, 3(2):91-107. 2. Räisänen et al., Climate Dynamics 2012;39:1981-1998. 3. Akaike H. IEEE Trans Auto Control 1974 (19):716-723.

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