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A Novel Cost Function in AIF Model Fitting for DCE-MRI Studies

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DCE IS HEAVILY DEPENDENT ON AIF

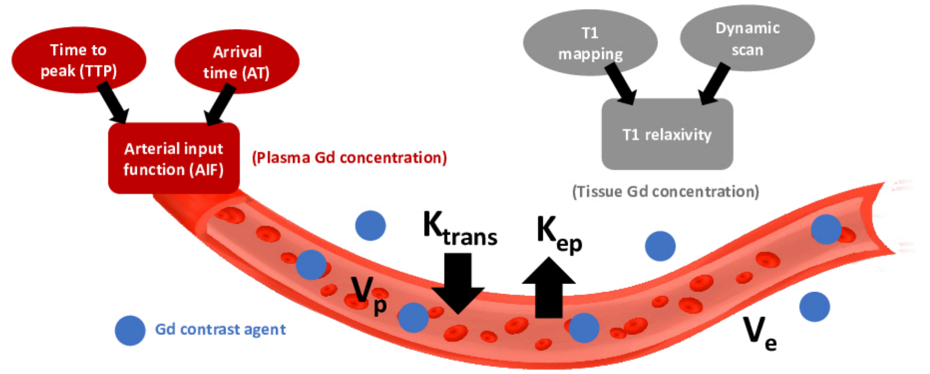

Figure 1. Factors influencing calculation of tracer-kinetic model based DCE parameter values (e.g. K_{trans}, V_e, etc.), among which AIF is one of the most crucial.

AN IMPROVED AIF CAN IMPROVE DCE

The arrival time **(AT)** and time to peak **(TTP)** of upslope for each arterial input function **(AIF)** time series are crucial parameters in quantitative dynamic contrast enhanced **(DCE)** MRI. We propose a *new method for accurate and automatic estimation of these parameters* that offers overall increased feasibility, faster computational time, superior accuracy, and greater stability when compared to current methodology in quantitative DCE MRI.

THE NOVEL COST FUNCTION

$$\mathrm{AIFM} = \min(\overbrace{\max\left(p1, p1 + (p2 - p1)\cdot\frac{t-\min(p4,p5)}{abs(p5-p4)} + (p3-p1)\cdot\frac{t-\min(p4,p5)}{abs(p5-p4)}\right)}^{part\ 1},$$
$$\overbrace{\min\left(uplimit, p2\cdot\exp\left(-p6\cdot(t-\max(p5,p4))\right) + p3\cdot\exp\left(-p7\cdot(t-\max(p5,p4))\right)\right)}^{part\ 2})$$

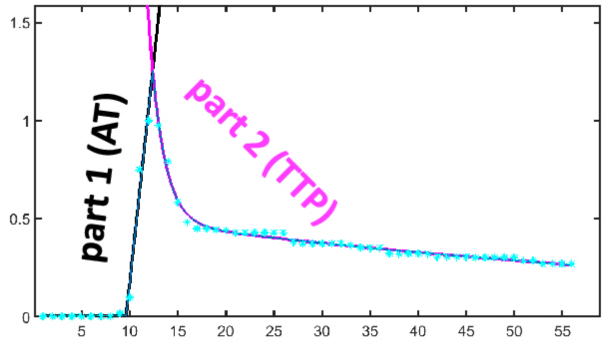

Figure 2. The fitting process for AT (black) and TTP (magenta) where a 56 time point AIF time series (cyan) is presented.

COST FUNCTION OPTIMIZATION

The fitting cost function is implemented by global optimization on **||DATA - AIFM||**, where DATA is DCE concentration or signal. The deterministic global optimization method Branch-And-Reduce Optimization Navigator (**BARON**) [1] is adopted for the fitting. BARON determines the global solution of nonconvex optimization problems which requires an algebraic description of the model [2]. Towards this purpose, our AIFM is constructed as described previously, making direct use of BARON. *Our special design of the new cost function of AIFM meets BARON's general assumptions and converges rapidly.*

IMAGE PRE-PROCESSING

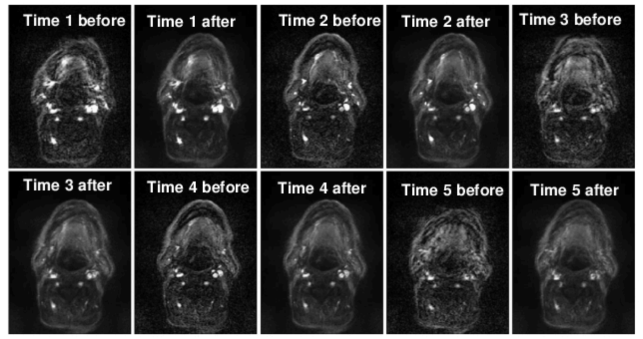

Figure 3. Spatial and temporal higher-order total variations (HOTVs) are applied on the series of DCE MRI to minimize variabilities caused by motion [3].

OUR NOVEL COST FUNCTION PROVIDES RELIABLE AND ACCURATE RESULTS

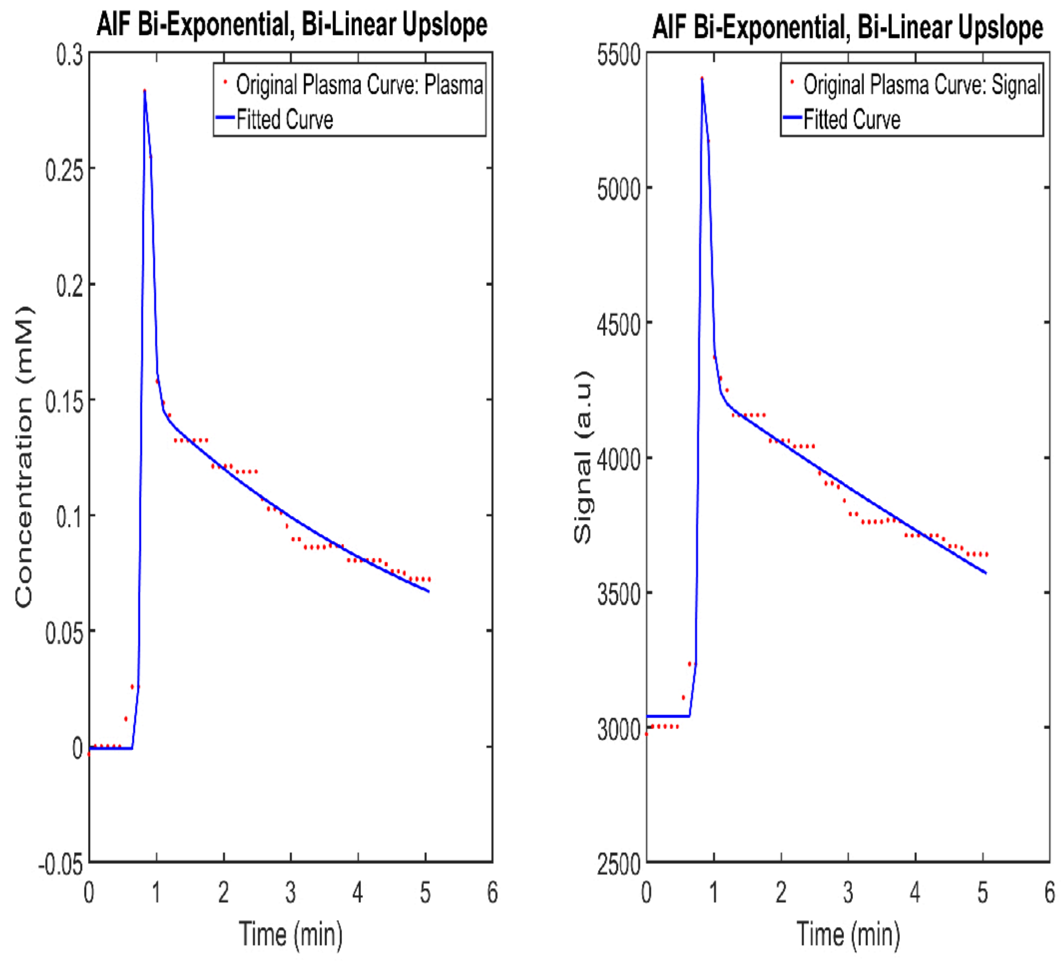

Figure 4. The practical AIF fitting results for DCE concentration (left) as well as DCE signal (right).

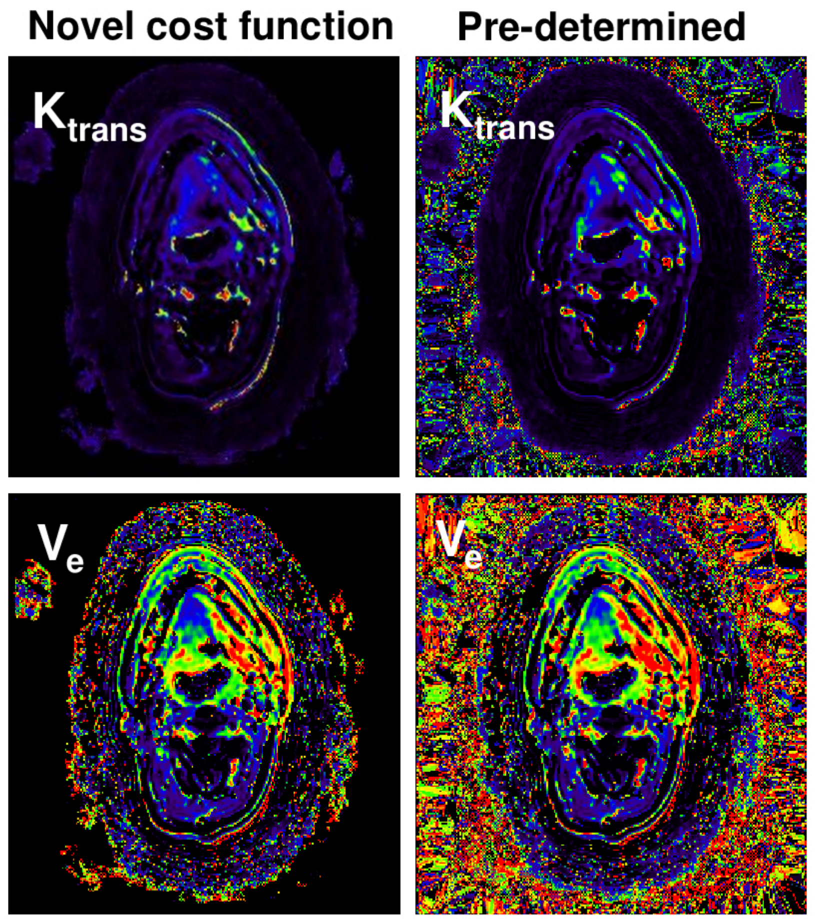

Figure 5. DCE map comparisons between automatic estimation of AT/TTP using the new cost function (left) and human predetermined AT/TTP (right). While maps are comparable, predetermination is time consuming and requires trial-and error to meet AIF fitting criteria.

DISCUSSION AND CONCLUSIONS

In previous studies for analytic AIF modeling, AT and TTP are usually predetermined and hinder the quality of fitting results [4,5]. Moreover, often it is simply infeasible to perform AIF measurements reliably due to data acquisition constraints. Herein we have shown that **our new method can precisely and efficiently fit the analytic models without deliberation on the determination of AT and TTP**, parameters that are typically difficult to obtain accurately due to inter- and intra-patient variabilities. Therefore, we propose that our method not only improves upon previous methodology in terms of feasibility and efficiency, but also offers an overall more robust and stable approach to analyzing DCE-MRI. Additionally, since our method relies on generalized parameter estimation, it can be *extrapolated to other AIF models such as the Parker model*. This methodology can be adapted into current DCE-MRI workflows to improve clinical implementation of these novel imaging techniques.

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CONTACT INFORMATION

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