

A threshold method to exclude unreliable tracer kinetic model parameters measured from DCE MRI in breast cancer

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Target audience:

Clinicians and researchers who analyze tracer kinetic parameter maps obtained using curve fitting of concentration-time curves from DCE MRI.

Purpose:

Model based tracer kinetic parameters in dynamic contrast-enhanced (DCE) MRI are derived using some curve fitting process. The reliability of the parameter value at each voxel has been an issue [1]. Two criteria for parameter values to be reliable are contrast to noise ratio (CNR) should not be too low and the curve fitting should be successful. We present a method to filter out unreliable voxels with low CNR and poor quality of fit. We analyzed how this filtering method affects the distribution of the parameter values. This is a part of our DCE-MRI projects on breast tumors.

Methods:

MRI scans were performed with a 3T MR scanner (Magnetom Trio; Siemens, Germany) and a breast receiver coil and a surface coil placed on the back of patients (n=9) for direct measurements of arterial input function from the descending aorta. 3D SPGR FLASH, pre-contrast T1 maps (TR=20ms, FA=5°, 13°, 20°, 256x256, 16 4-mm thickness slices) and subsequent dynamic acquisition (TR=4ms, FA=15°, 128x128 interpolated to 256x256, 2.4s per frame for 200 frames) [2]. On the seventh dynamic time-point, 0.1 mmol/kg of body weight dosage of 0.5 M Gadolinium-based contrast agent (Magnevist, Bayer, Germany) was administered through a power injector at 3 ml/s. Tumor ROIs were drawn by a radiologist. Voxel-level contrast concentration-time curves extracted from the tumor region on all slices were analyzed using a two-compartment axially distributed parameter model [3]. We analyzed 18 whole tumors at the end of a 14-days cycle chemotherapy treatment.

We defined CNR as the ratio of the maximum of the concentration-time curve and the standard deviation (SD) of last four minutes data considering a fitted quadratic curve as the true value. For goodness of fit, we use the fraction of modeling information (FMI) proposed by Balvay et al. [4]. Balvay et al. theoretically defined $FMI = 1 - \frac{\|e\|^2}{\|d_0\|^2}$, where e represents the modeling errors and d_0 represents the true data. For a robust regression, the modeled data (m) and the modeling errors can be assumed to be independent. Then $\|d_0\|^2$ can be approximated by $\|m\|^2 + \|e\|^2$ and the FMI by $\|m\|^2 / (\|m\|^2 + \|e\|^2)$. Thus, in a way FMI describes how much of the true data are represented by the modeled data, and FMI approaches 1 implies that the model is representing the data well. We used the first four minutes for our FMI computation as the latter data points were very well fit in almost all cases. The thresholds for CNR and FMI used were 15% and 0.995, respectively.

We performed paired Student's t-test to test whether the above filter reduced the SD, and affected the mean and median values. Significant level set at $P < 0.05$.

Results:

Fig. 1 illustrates different curve fitting qualities. Note that root mean squared error (RMSE) and FMI show different qualities of fit. Fig. 2 shows the different ROIs before and after filtering. CNR mainly filtered out the surrounding voxels likely affected by partial volume and some lowly enhanced, probably necrotic regions. Voxels filtered out by FMI were less spatially related than CNR. Fig. 3 shows parameter histograms after filtering out unreliable voxels became more Gaussian like. Table 1 shows the P-values of the above statistical tests. SD of all parameters were significantly reduced while means and medians of only a few parameters (P -values in bold) were not significantly different after filtering.

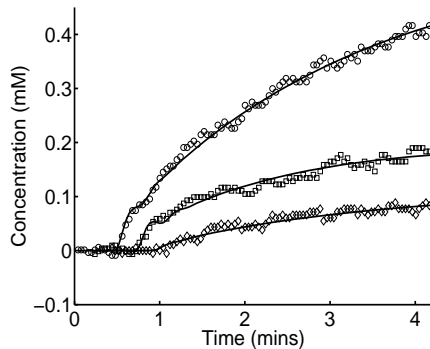


Fig. 1 Three voxel-level concentration-time curves offset by 12s from each other with quality of fit according to FMI from good to poor: RMSE, CNR and FMI values are 8.9×10^{-4} , 49.6% and 0.9995 (top), 9.3×10^{-4} , 19.7% and 0.9950 (middle), and 6.6×10^{-4} , 21.1% and 0.9913 (bottom), respectively.

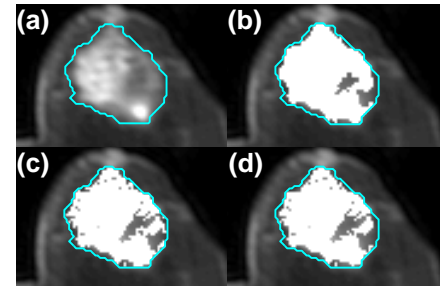


Fig. 2 (a) Manually drawn ROI (cyan), (b) mask of ROI after filtered by rejecting CNR < 15%, (c) FMI < 0.995, and (d) both CNR and FMI thresholds, are overlaid on a post-contrast enhanced T1w image.

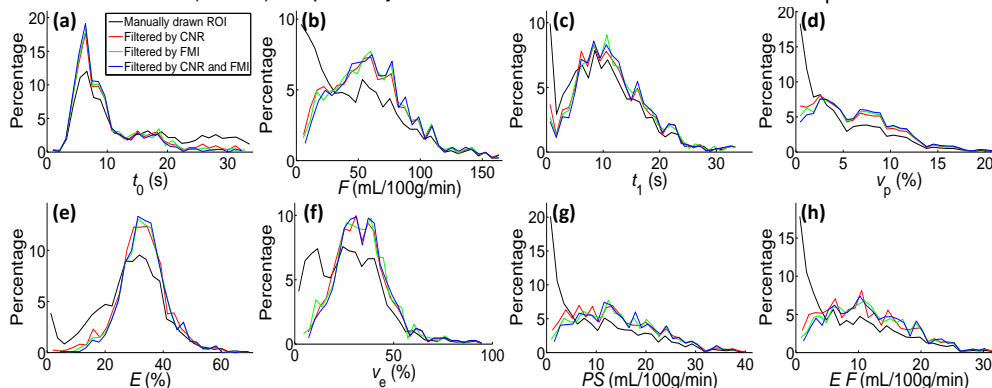


Fig. 3 Histograms of parameters in a typical case: without filtering (black) and with filtering by CNR (red), FMI (green) and both CNR and FMI (blue). (a) Bolus arrival time (t_0), (b) perfusion (F), (c) mean vascular transit time (t_1), (d) fractional plasma volume (v_p), (e) first pass extraction fraction (E), (f) fractional extravascular extracellular volume (v_e), (g) vessel permeability surface area product (PS), (h) $E-F$.

Table 1. P values of paired Student's t-test the effect on SD, mean and median of parameters after filtering by CNR and FMI. P value > 0.05 are in bold.

Alternate hypothesis	t_0	F	t_1	v_p	E	v_e	PS	$E-F$
SD was reduced	0.048	0.016	0.001	0.002	0.003	0.000	0.030	0.031
Means were different	0.209	0.000	0.062	0.000	0.030	0.277	0.002	0.001
Medians were different	0.207	0.000	0.014	0.006	0.032	0.086	0.002	0.002

based tracer kinetic analysis of DCE MRI data.

References:

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