DCE MRI Pixel-by-pixel Quantitive Curve Pattern Analysis (CPA)

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Introduction

DCE-MRI is a valuable technique for the pharmacodynamic assessment of antivascular and antiangiogenic agents in clinical applications. There are several factors (e.g. choice of pharmacokinetic model, selection of an arterial input function (AIF), and accuracy of the intrinsic baseline T_1 measurement) which can significantly influence the accuracy and repeatability of DCE-MRI results. And these have prevented DCE-MRI further clinical applications.

In this abstract, we presented a novel method, called curve pattern analysis (CPA), which could improve the repeatability of DCE-MRI results without requirements of AIF and the baseline T_1 measurement. It is demonstrated in simulations that new CPA quantitative parameters are approximately insensitive to acquisition protocols. In human studies, parametric maps for both the pharmacokinetic model and the CPA method are presented and compared.

Methods

The segment over the first 3 minutes after bolus injection is separated from the signal intensity curve as shown in Fig. 1a. The scaled curve S_c is computed from this 3-min segment (S) using Eq (1).

$$S_c(t) = \frac{S(t) - S_b}{S_{3\min} - S_b} \qquad (1) \qquad\qquad \kappa = \frac{\beta_1(1-\beta_2)}{\beta_\tau} \qquad (2)$$

Where S_b is the averaged baseline signal intensity; S_{3min} is the signal intensity at 3-minute point after bolus injection. The scaled 3-min curve subtracts the diagonal dashed line shown in Fig. 1b to get a new curve shown in Fig. 1c. The maximum point is marked in this new curve. In Fig. 1d and 1e, five areas (A_1, A_2, A_Δ, A_τ, and A_{3min}) are defined based on the scaled curve and the maximum point. Four new CPA parameters are defined according to these areas. $\beta_1 = A_1 / A_\Delta$; $\beta_2 = A_2 / A_\Delta$, and A_2 can be positive or negative; $\beta_\tau = \tau$ / 3min, and τ is calculated when the ratio of the sparse dotted area (A_τ) to the total area A_{3min} is equal to 1/3. Curve pattern analysis (CPA) factor κ is defined in Eq (2) according to the above three parameters.

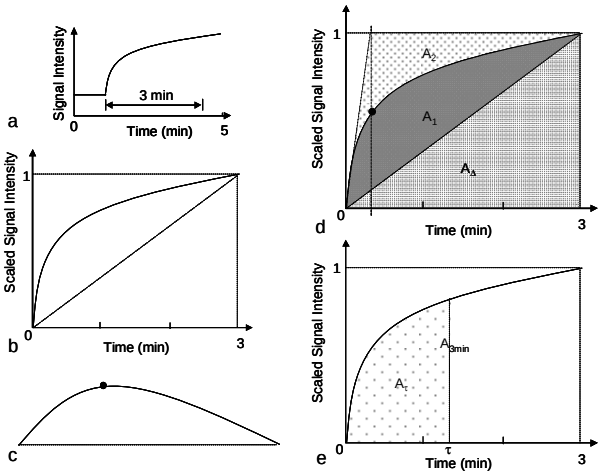

Fig. 1. (a) The original signal curve; (b) The scaled 3-min curve using Eq (1) ; (c) The maximum point (black dot); (d) Three defined regions A_1, A_2, and A_Δ, the black point is the maximum point in (c); (e) Two defined regions A_τ, and A_{3min} which represents the total area under the scaled signal curve.

A series of simulations were performed to investigate the dependency of the four new defined CPA parameters on T_1, TR and the flip angle which are three main variables in the gradient echo signal intensity equation. A concentration curve was created using the experimentally-derived AIF and Tofts' pharmacokinetic model (K^{trans} = 0.5 min^{-1}, v_e= 0.4) (1,2). The different signal intensity curves were generated from the same concentration curve using the different protocol parameter values according to the gradient echo signal equation. CPA parameters were then calculated according to the above described procedures.

In the human studies, DCE-MRI data were acquired before chemotherapy from a pediatric patient with Osteosarcoma (OS). DCE MRI data was acquired using a 3D FLASH pulse sequence. The protocol was as follows: 16 coronal slices, FOV = 25 cm × 25 cm; slice thickness = 5 mm; TE/TR = 1.24/3.5 ms; each acquisition time is 7 seconds for total 50 measurements. The data were processed using both Tofts' and our new CPA method.

Results

Fig. 2 shows that all CPA parameters were almost independent of the baseline T_1; CPA parameters changes slightly with TR, but they were approximately constant within a small range of TR; CPA parameters were almost constant when flip angle was larger than 20°. Fig. 3 shows CPA parametric maps and k_{ep} and K^{trans} maps. Results of κ and k_{ep} were very similar.

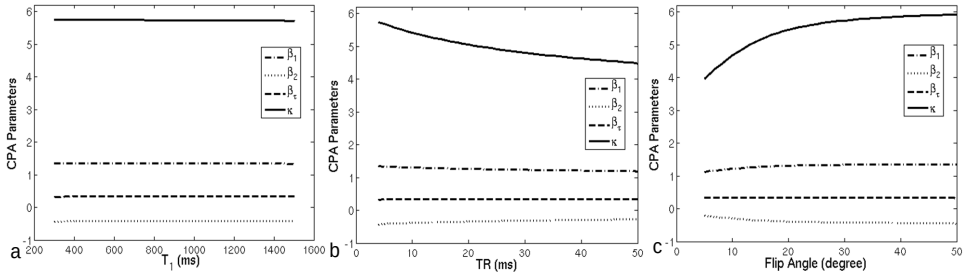

Fig. 2. Effects of T_1, TR and flip angle on CPA parameters.

Conclusion

The CPA method is simple and straightforward to characterize and quantify the signal curves from the DCE MRI data. All the CPA parameters are approximately independent of T_1, TR and flip angle under certain conditions. The CPA method could increase the repeatability without requiring additional information such as AIF and T_1 maps. The CPA parameter κ is very sensitive to the curve pattern and well correlated with k_{ep}.

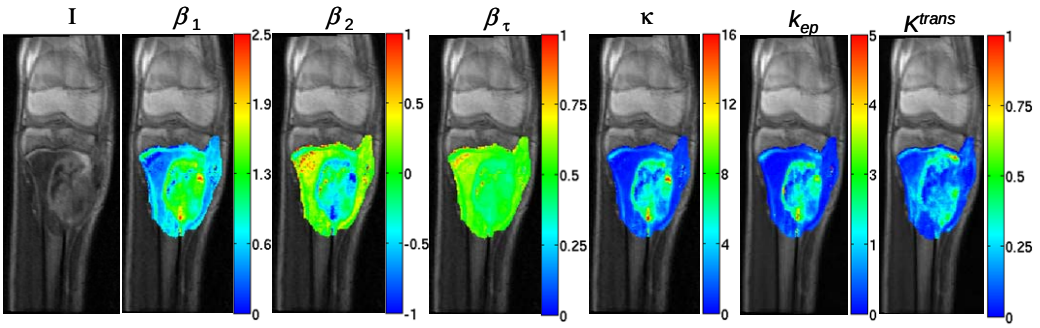

Fig. 3. Contrast-enhanced tumor image (I) , CPA parameter (β_1, β_2, β_τ, κ) maps, k_{ep} and K^{trans} maps.

Reference

1. Parker GJ, et. al. Magn Reson Med 2006;56(5):993-1000.
2. Tofts PS, et. al. Magn Reson Med 1991;17(2): 357-367.