Quantitative analysis of clinical dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) to evaluate treatment response in human breast cancer

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Introduction: Neoadjuvant chemotherapy (NAC) has become more common for treatment of breast cancer prior to surgery. In spite of usefulness of quantitative DCE-MRI in treatment assessment, this technique still has not been adopted in routine clinical practice because of several major practical limitations, including: 1) difficulty in obtaining an accurate arterial input function (AIF); 2) the long scanning time needed to acquire 3D data with high spatial resolution and a high signal-to-noise ratio (SNR) for accurate estimation of baseline T1(0); and 3) highly variable and even considerable percentage of unphysical results generated by conventional methods due to noise effects. Other practical difficulties include the long computational time associated with the non-linear least square fit method (NLS) commonly used in quantitative DCE-MRI. In this study, we develop a method (T1-FCM) that combines a fixed-T1 method, the Fuzzy C-Means (FCM) technique and the reference region (RR) model to overcome the aforementioned difficulties in estimating pharmacokinetic parameters from clinical DCE-MRI without measuring either an AIF or T1(0), and demonstrate its feasibility to assess treatment response to NAC in patients with breast cancer using routinely acquired clinical DCE-MRI data.

Methods and Materials: All MR studies were performed at a 1.5 Tesla whole-body MR clinical scanner (Signa Excite 1.5T; GE Healthcare, Milwaukee) using a four-channel phased-array breast receive coil. DCE-MRI were obtained with a T1-weighted fast 3D short TR spoiled gradient echo sequence with fat suppression (TR = 6.65 ms, TE = 1.56 ms, flip angle = 15°, slice thickness=3mm, matrix=512×512) before treatment and after two cycles of NAC. The median time interval between pretreatment MR imaging and the start of chemotherapy was 1 day. One pre-contrast and seven post-contrast series were obtained at an interval of 58 seconds. 17 patients with biopsy-proven breast cancer participated in this study, and all gave written informed consent approved by the Human Investigation Committee of participating Institutes. The specific neoadjuvant chemotherapy (NAC) regimen of each patient was determined on an individual basis by their oncologists. Histopathologic response was assessed based on excised surgical specimens according to the scheme proposed by Ogston et al2. For the five grades of the scheme, grade 4 or 5 was classified as major histological response (MHR) and grade 1 to 3 was classified as non-major histological response (NMHR).

DCE-MRI data were processed by T1-FCM method with in-house developed software written in Matlab 7.6 (MathWorks, Inc., Natick, MA, USA).

T1-FCM method includes the following steps: 1) segment tumor area using a FCM-based technique5 and delineate the RR area (muscle); 2) estimate baseline tumor T1(0) value using the relationship between T1 in the tumor (T1tumor) and T1 in the reference region by the following equation:

\[ T_{\text{tumor}}(0) = \frac{T_{\text{tumor}}(0)-\cos\theta T_{\text{RR}}(0)+\cos\theta T_{\text{RR}}}{(1-\cos\theta)N_{\text{RR}}} \]

where \( N_{\text{RR}} \) is proton density ratio between tumor and RR (\( \rho_{\text{tumor}}/\rho_{\text{RR}} \)). \( T_{\text{tumor}}(0) \) can be roughly estimated by the ratio between averaged signal intensity over tumor and that in the RR (\( S_{\text{tumor}}/S_{\text{RR}} \)) and literature T1 of tumor (1151ms) and RR (869 ms) using FLASH signal intensity equation.

3) Convert signal intensities of tumor and RR to CA concentration \( C(t) = \frac{1}{T1(t)} - \frac{1}{T1(0)} \) where \( T1(0) \) and \( T1(t) \) are acquired clinical DCE-MRI data.

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Conclusion: We have demonstrated the feasibility of T1-FCM method to assess treatment response to NAC in patients with breast cancer using routine clinical DCE-MRI data without measurement of AIF and T1(0). This method could prove useful for evaluation of breast cancer therapy.

Reference:

Fig. 1 Illustration of estimated tumor volume and \( K_{\text{trans}} \) of a patient with IDC before treatment and after two cycles of NAC. (A) Tumor size (in cm³) before (red) and after (blue) the NAC; (B) Histograms of \( K_{\text{trans}} \) before (red color) and after (blue color) the NAC; (C) 3D \( K_{\text{trans}} \) map before treatment; (D) \( K_{\text{trans}} \) map after one cycle of NAC.