Improved quantification of pharmacokinetic parameters at 3 Tesla considering B₁ inhomogeneities

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Introduction: The technique of dynamic contrast-enhanced (DCE) T1-weighted MRI provides a widespread method to determine kinetic parameters of human tissues [1, 2]. The principle of this method is the analysis of the time-variant signal intensities of the DCE data. But for field strength above 1.5 T B₁ inhomogeneities produce considerable intensity variations in the abdominal region which strongly affect the estimation of the kinetic parameters. The aim of this work was to investigate the influence of B₁ inhomogeneities on the kinetic parameters K⁺ and Vₑ and the potential improvement of the data using the measured flip angle distribution for the correction of these inhomogeneities.

Methods: Using a DCE scan and a proton density weighted reference scan the temporal T₁ relaxation can be calculated with the method recommended by Hittmair [3]. The time-dependent contrast agent concentration C(t) follows from equation (2) using a relaxivity rₑ of 3.7 L mmol⁻¹ s⁻¹. In order to correct the data with respect to the B₁ inhomogeneities a dedicated STEAM sequence [4] was used which measures the actual flip angle distribution. Formula (3) describes the Tofts-model which was used for the estimation of the kinetic parameters K⁺ and Vₑ. C(t) is the time-dependent tracer concentration in the tissue and C₀(t) represents the AIF and is the time-dependent tracer concentration in arterial whole blood. Hct represents the hematocrit, Vₑ is the volume of extravascular extracellular space per unit volume of tissue and K⁺ is the volume transfer constant between blood plasma and Vₑ. This model was fitted to the dynamic concentration data in order to obtain values for the two free parameters K⁺ and Vₑ. For the statistical analysis of the kinetic parameters the mean value, the deviation of the mean values using two comparable AIFs (left and right arteria iliaca communis) and the coefficient of variation (CV) described in formula (3) are calculated for different regions of interest in the left and right musculus gluteus maximus. All results were calculated without and with the correction of the B₁ inhomogeneities and were checked against each other. The measurements were performed for a group of 9 persons using a 3.0 T MRI scanner (Magnetom Tim Trio, Siemens Medical, Germany).

Results: Fig.1 (a) shows a DCE image of the pelvis region including the magenta-marked regions which indicate the left/right AIF and the 4 regions of interest used for the calculation of the required kinetic parameters. Fig.1 (b) and (c) show the comparison of the mean value of K⁺ and Vₑ for a selected subject. The blue and cyan bar represent the values obtained with the left and right AIF without B₁ correction and the red and magenta bar represents the values obtained with B₁ correction.

![Fig. 1: (a) DCE image of the pelvis region with the respective regions of interest, (b) mean value of K⁺, (c) mean value of Vₑ.](image)

Fig. 2 (a) and (b) show the coefficient of variation of K⁺ and Vₑ for all 4 regions for a selected subject. The blue and cyan bar represent the CV of the kinetic parameters obtained with the left and right AIF without the correction of the B₁ inhomogeneities and the red and magenta bar represent the CV obtained with B₁ correction. Fig. 2 (c) and (d) show the comparison of the absolute deviation of K⁺ and Vₑ with respect to the left and right AIF for all subjects. The bars colored from blue to cyan represent the values obtained for regions 1 - 4 without B₁ correction and the bars colored from red to magenta represent the values obtained with B₁ correction.

![Fig. 2: Statistical analysis: (a) coefficient of variation of K⁺, (b) coefficient of variation of Vₑ, (c) absolute deviation of K⁺, (d) absolute deviation of Vₑ.](image)

Discussion: The determination of kinetic parameters depends strongly on the inhomogeneities of the RF-field which can be seen in fig. 1 (c,d). Due to the local magnitude of these inhomogeneities the obtained values for the AIF and time-dependent tissue concentrations are widespread which lead to an overestimation or underestimation of K⁺ and Vₑ. An essential improvement can be achieved if the dynamic data are corrected accordingly. The absolute difference of K⁺ and Vₑ obtained with the AIF in the left and right arteria iliaca communis (fig. 2 (c,d)) can be improved by a factor up to 33 when using the correction procedure. Also the coefficient of variation of the kinetic parameters could be improved which can be seen in fig. 2 (a,b).

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