Improved quantification of pharmacokinetic parameters at 3 Tesla considering B_1 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 B_1 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 B_1 inhomogeneities on the kinetic parameters K^{trans} and V_e 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 T_1 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 r_1 of 3.7 L mmol^{-1} s^{-1}. In order to correct the data with respect to the B_1 inhomogeneitis 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^{trans} and V_e. $C_T(t)$ is the time-dependent tracer concentration in the tissue and $C_A(\tau)$ represents the AIF and is the time-dependent tracer concentration in arterial whole blood. Hct represents the hematocrit, V_e is the volume of extravascular extracellular space per unit volume of tissue and K^{trans} is the volume transfer constant between blood plasma and V_e. This model was fitted to the dynamic concentration data in order to obtain values for the two free parameters K^{trans} and V_e. 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 B_1 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).

$$C(t)=\left(\frac{1}{T_1(t)}-\frac{1}{T_{10}}\right)\cdot\frac{1}{r_1} \quad (1)$$

$$C_T(t)=K^{trans}\cdot\int_0^{t_M}\frac{C_A(\tau)}{(1-Hct)}\cdot e^{-\frac{K^{trans}}{V_e}(t-\tau)}d\tau \quad (2)$$

$$CV=\frac{Std(x)}{Mean(x)} \quad (3)$$

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^{trans} and V_e for a selected subject. The blue and cyan bar represent the values obtained with the left and right AIF without B_1 correction and the red and magenta bar represents the values obtained with B_1 correction.
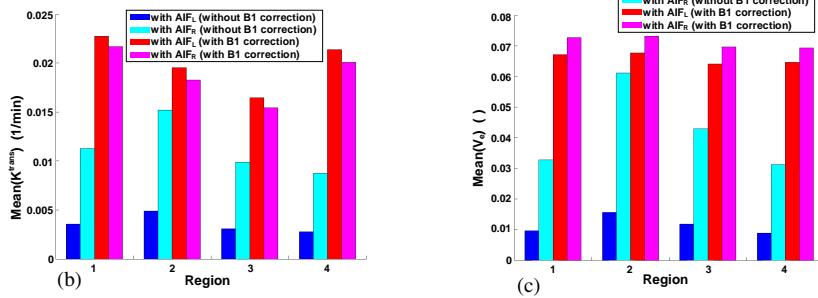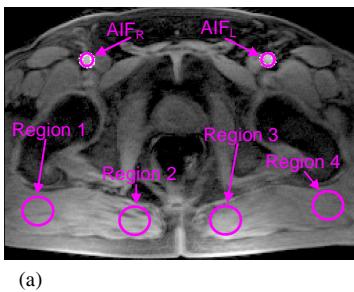

Fig. 1: (a) DCE image of the pelvis region with the respective regions of interest, (b) mean value of K^{trans} , (c) mean value of V_e

Fig. 2 (a) and (b) show the comparison of the coefficient of variation of K^{trans} and V_e 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 B_1 inhomogeneities and the red and magenta bar represent the CV obtained with B_1 correction. Fig. 2 (c) and (d) show the comparison of the absolute deviation of K^{trans} and V_e 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 B_1 correction and the bars colored from red to magenta represent the values obtained with B_1 corretion.
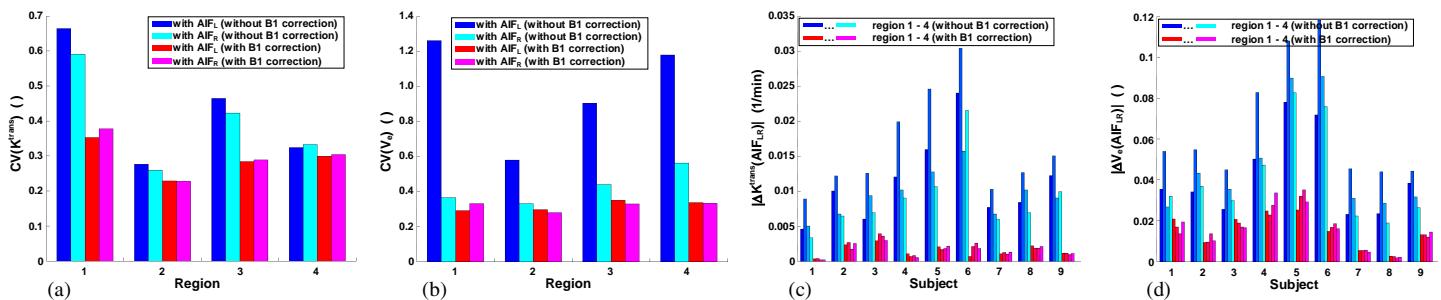

Fig. 2: Statistical analysis: (a) coefficient of variation of K^{trans} , (b) coefficient of variation of V_e ,(c) absolute deviation of K^{trans} , (d) absolute deviation of V_e

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^{trans} and V_e. An essential improvement can be achieved if the dynamic data are corrected accordingly. The absolute difference of K^{trans} and V_e 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).

References: [1] S.M. Galbraith, NMR Biomed., 15, 132-142 (2002), [2] P.S. Tofts, J. Magn. Reson. Imaging, 10, 223-232 (1999), [3] K. Hittmair, Magn. Reson. Med. 31, 567-571 (1994), [4] W.H. Perman, Magn. Reson. Med. 9, 16-24 (1989)