Impact of B_1-Inhomogeneities on the Quantification of K^{trans} and V_e

R. Merwa[1], T. Feiweier[2], F. Ebner[3], G. Reishofer[3], K. Kapp[4], and R. Stollberger[5]

[1]Medical Engineering, FH OÖ - Upper Austria University of Applied Sciences, Linz, Austria, [2]Healthcare, Siemens AG, Germany, [3]Department of Radiology, Medical University of Graz, Graz, Austria, [4]Department of Radiation Therapy, Medical University of Graz, Graz, Austria, [5]Institute of Medical Engineering, Graz University of Technology, Graz, Austria

Introduction: Dynamic contrast-enhanced (DCE) T1-weighted MRI provides a widespread method to determine kinetic parameters of human tissues [1, 2]. The quantification of these parameters relies on the deconvolution with the arterial input function (AIF), which can be determined from the signal changes in a major artery. 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 objective 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 these parameters using the measured flip angle distribution for the correction of these intensity variations.

Methods: The temporal T_1 relaxation can be calculated with the method recommended by Hittmair [3] by using a DCE scan and a proton density weighted reference scan. The contrast agent concentration C(t) can be calculated with equation (1) using a relaxivity r_1 of 3.7 L mmol^{-1} s^{-1}. For the correction of the data with respect to the B_1 inhomogeneitis a special STEAM sequence [4] was used which measures the actual flip angle distribution. The Tofts-model described in (2) 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 4 different regions of interest in the left and right musculus gluteus maximus. All results were calculated with and without the correction of the B_1 inhomogeneities and were checked against each other. The measurements were performed for a group of 9 subjects using a 3.0 T MRI scanner (Magnetom Tim Trio, Siemens Medical, Germany).

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

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

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

Results: Fig.1 (a) shows a DCE image of the pelvis region with the magenta-marked regions which indicate the left/right AIF and the 4 regions of interest using for the calculation of the required kinetic parameters. Fig.1 (b) shows the comparison of the right and left AIF obtained with B_1 correction (red, magenta) and without B_1 correction (blue, cyan). Fig.1 (c) and (d) show the comparison of the mean value of K^{trans} and V_e for a selected subject. The magenta and red bar represent the values obtained with the right and left AIF with B_1 correction and the cyan and blue bar represents the values obtained without B_1 correction.

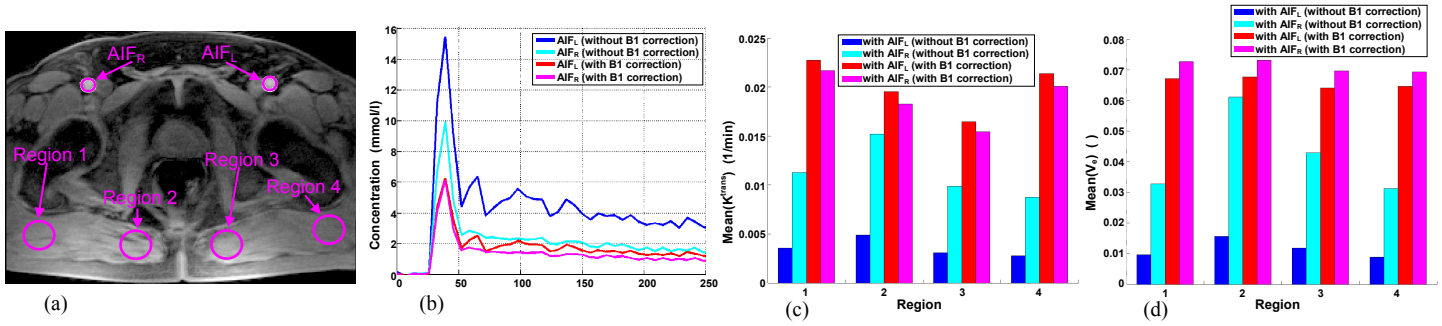

Fig. 1: (a) DCE image of the pelvis region with the respective regions of interest, (b) right and left AIF, (c) mean value of K^{trans}, (d) mean value of V_e

Fig. 2 (a) and (b) show the comparison of the absolute deviation of K^{trans} and V_e with respect to the right and left AIF for all subjects. The bars colored from red to magenta represent the values obtained for regions 1 - 4 with B_1 correction and the bars colored from blue to cyan represent the values obtained without B_1 correction. Fig. 2 (c) and (d) show the comparison of the coefficient of variation (CV) of K^{trans} and V_e for all 4 regions for a selected subject. The red and magenta bar represent the CV of the kinetic parameters obtained with the left and right AIF with the correction of the B_1 inhomogeneities and the blue and cyan bar represent the CV obtained without B_1 correction.

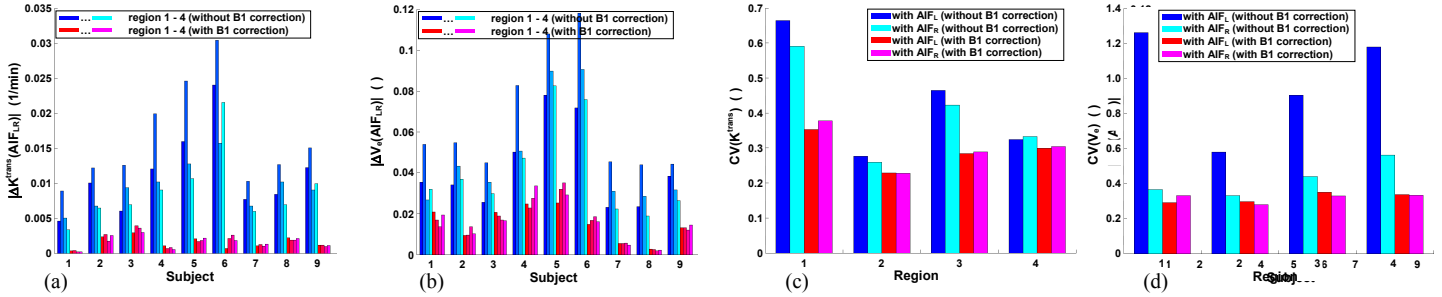

Fig. 2: Statistical analysis: (a) absolute deviation of K^{trans}, (b) absolute deviation of V_e, (c) coefficient of variation of K^{trans}, (d) coefficient of variation of V_e

Discussion: The determination of the AIF and of the kinetic parameters depends strongly on the inhomogeneities of the RF-field which can be seen in fig. 1 (b, 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 (a, b)) 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 (c, d).

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)