Improvement of the Arterial Input Function considering B_1-Inhomogeneities

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Introduction: RF-field inhomogeneities are a main source for image inhomogeneities and systematic errors in quantification of pharmacokinetic parameters [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. In particular for field strength above 1.5 T RF-field inhomogeneities provoke considerable intensity variations in the abdominal region which significantly influence the determination of the AIF. The objective of this work was to investigate the B_1-inhomogeneity dependent influence of vessel selection for the AIF determination, the impact on quantification of the pharmacokinetic parameters K^{trans} and V_e in a region of interest (ROI) and the possibility to correct these inhomogeneities by using the measured flip angle distribution.

Methods: The DCE imaging was performed using a 3D FLASH sequence with the following parameters: T_R = 3.34 ms, T_E = 1.1 ms, FA = 15°, N_x x N_y = 256 x 256 matrix size, FOV_x = FOV_y = 300, mm, TH = 4 mm, slices = 20 (no gaps), time points = 40, acquisition time ~ 7 min. The contrast media concentration was determined by a method mentioned by Hittmair [3] using a proton density weighted reference scan (3D FLASH) with T_R = 100 ms, T_E = 1.1 ms and FA = 5°. All other parameters were consistent with the DCE scan parameters. The actual flip angle distribution, which is proportional to the active RF-field component B_1 was measured with a STEAM sequence [4]. The parameters of this sequence were: T_R = 1200, T_E = 14 ms, FA = 90°, N_x x N_y = 52 x 64 matrix size, FOV_x = 308 mm, FOV_y = 250 mm, TH = 5 mm, slices = 19 (10 mm gap), acquisition time ~ 1 min. Using equation (1) the temporal T_1 relaxation can be calculated from the reference and the DCE images [3]. SI_R, $SI_D(t)$ and T_R are the signal intensity of the reference scan, the signal intensity of the dynamic scan at the time point t and the repetition time of the DCE scan respectively. α_D and α_P are the nominal and the corrected flip angles of the dynamic and the reference scan respectively. The contrast agent concentration C(t) follows from equation (2) using a relaxivity r_1 of 3.7 L mmol^{-1} s^{-1}. The Tofts-model (3) was used for the estimation of the kinetic parameters K^{trans} and V_e. $C_T(t)$ represents the tracer concentration in the tissue at time t and $C_A(\tau)$ represents the AIF which is the tracer concentration in the arterial whole blood at time τ. 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 K^{trans} and V_e. For the analysis of the AIFs the maximum values and the root mean square deviation of the left to the right AIF were calculated. For the analysis of the kinetic parameters the absolute deviation between the values obtained with the left and right AIF were determined. All results were calculated with and without B_1 correction 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).

$$T_1(t) = -\frac{T_R}{\ln\left(\frac{SI_R \cdot \sin(\alpha_D) - SI_D(t) \cdot \sin(\alpha_R)}{SI_R \cdot \sin(\alpha_D) - SI_D(t) \cdot \sin(\alpha_R) \cdot \cos(\alpha_D)}\right)} \quad (1)$$

$$C(t) = \left(\frac{1}{T_1(t)} - \frac{1}{T_{10}}\right) \cdot \frac{1}{r_1} \quad (2)$$

$$C_T(t) = K^{trans} \cdot \int_0^{t_M} \frac{C_A(\tau)}{(1 - Hct)} \cdot e^{-\frac{K^{trans}}{V_e}(t-\tau)} d\tau \quad (3)$$

Results: Fig.1 (a) shows a DCE image of the pelvis region including the magenta-marked regions for the right and left AIF and for the ROI used for the calculation of the kinetic parameters with and without B_1 correction. Fig.1 (b) shows the flip angle distribution (0° - 120°) for a selected slice. Fig.1 (c) and (d) show the comparison of the left and right AIF (of two selected subjects) obtained with (red, magenta) and without (blue, cyan) B_1 correction.

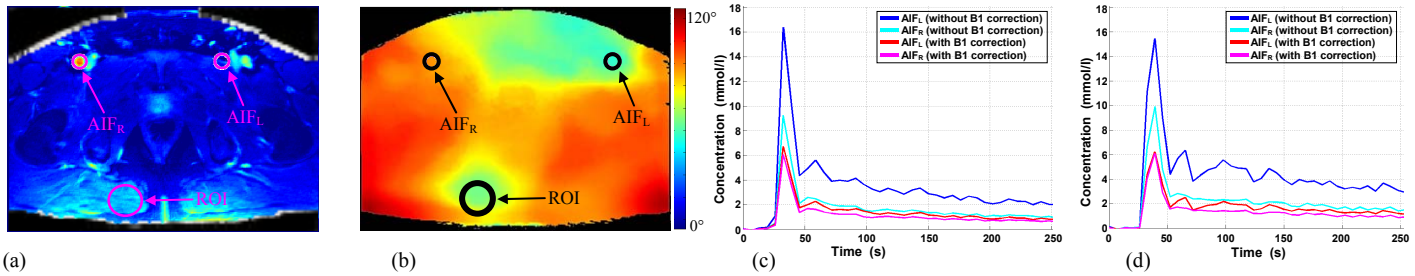

Fig. 1: (a) DCE image with the regions of interest, (b) Flip angle image, (c) and (d) left and right AIF of 2 selected subjects

Fig.2 (a) and (b) show the comparison of the maximum values and the root mean square deviation (RMSD) of the left to the right AIF for all 9 subjects. The red and magenta bar represents the values obtained with B_1 correction and the blue and cyan bar represents the values obtained without B_1 correction. Fig. 2 (c) and (d) show the absolute deviation of K^{trans} and V_e in the ROI obtained with the left and right AIF. The red bar represents the values obtained with B_1 correction and the blue bar represents the values obtained without B_1 correction.

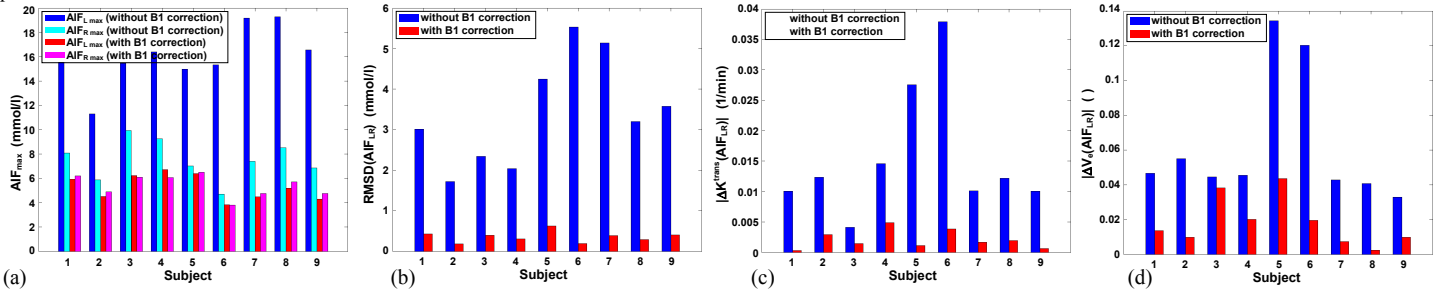

Fig. 2: (a) maximum values of the AIF, (b) root mean square deviation of the left to the right AIF, (c) absolute deviation of K^{trans}, (d) absolute deviation of V_e

Discussion: Dynamic contrast-enhanced MRI was performed at 3.0 T in combination with a dedicated sequence for the determination of B_1 inhomogeneities. AIF and tissue concentrations were calculated and the kinetic parameters K^{trans} and V_e were determined by means of a generalized kinetic model. The absolute deviation of the maximum values of the left and right AIF can be improved by a factor up to 70 and the root mean square deviation concerning the left to the right AIF can be decreased by factor up to 30 if B_1 inhomogeneities are corrected accordingly. Also the absolute deviations of the kinetic parameters K^{trans} and V_e in the selected ROI obtained with the left and right AIF are significantly lower with the proposed correction algorithm.

References: [1] P.S. Tofts, J. Magn. Reson. Imaging, 10, 223-232 (1999), [2] A.R. Padhani, NMR Biomed., 15, 143-153 (2002), [3] K. Hittmair, Magn. Reson. Med. 31, 567-571 (1994), [4] W.H. Perman, Magn. Reson. Med. 9, 16-24 (1989)