Impact of B_1 inhomogeneities on AIF selection in DCE-MRI at 3 Tesla

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Introduction: Dynamic contrast-enhanced (DCE) MRI is widely used to study 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. In particular for field strength above 1.5 T RF-field inhomogeneities provoke considerable intensity variations in the abdomen which affect the determination of the AIF (AIF of two comparable arteries diverges significantly). The aim 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 the RF-field inhomogeneities by using the measured flip angle distribution.

Methods: A 3D FLASH sequence was used for DCE-MRI 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 dedicated 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 the reference and the DCE images the temporal T_1 relaxation can be calculated using equation (1) [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 either the nominal flip angles or 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 described in formula (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 and is the tracer concentration in 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 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 without and with B_1 correction 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).

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

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

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

Results: Fig.1 (a) shows a DCE image of the pelvis region including the magenta-marked regions for the left and right AIF and for the ROI used for the calculation of the required kinetic parameters with and without B_1 correction. Fig.1 (b) shows the comparison of the left and right AIF obtained with (red, magenta) and without B_1 correction (blue, cyan). Fig.1 (c) and (d) show the comparison of the maximum values and the root mean square deviation (RMSD) of the left to the right AIF. The blue and cyan bar represent the values obtained without B_1 correction and the red and magenta bar represent the values obtained with B_1 correction.

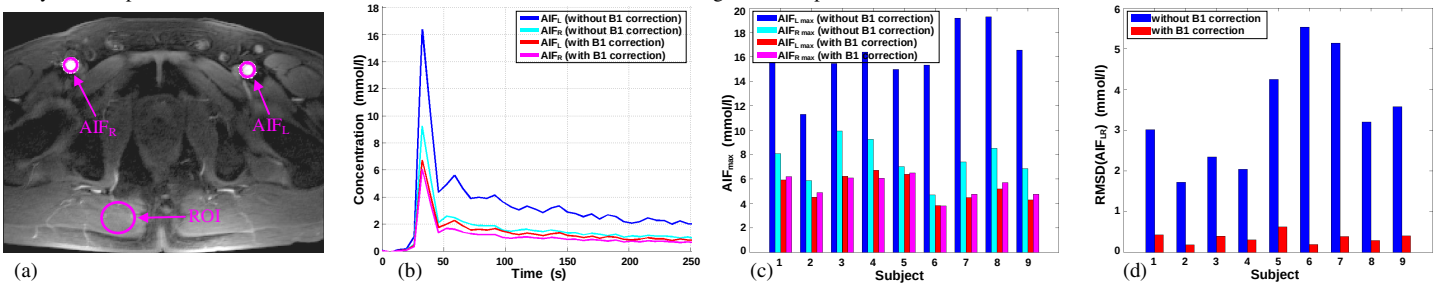

Fig. 1: (a) DCE image with the regions of interest, (b) left and right AIF, (c) maximum values of the AIF, (d) root mean square deviation of the left to the right AIF

Fig. 2 (a) and (b) show the comparison of K^{trans} and the absolute deviation of K^{trans} for the ROI obtained with the left and right AIF. Fig. 2 (c) and (d) show the comparison of V_e and the absolute deviation of V_e for the ROI obtained with the left and right AIF. The blue and cyan bar represent the values obtained without B_1 correction and the red and magenta bar represent the values obtained with B_1 correction.

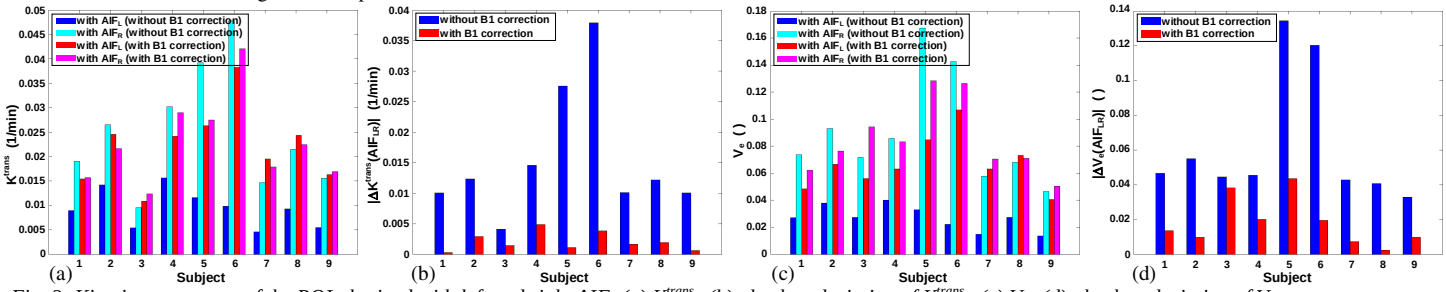

Fig. 2: Kinetic parameters of the ROI obtained with left and right AIF: (a) K^{trans}, (b) absolute deviation of K^{trans}, (c) V_e, (d) absolute deviation of V_e

Discussion: Dynamic contrast-enhanced MRI was performed at 3.0 T in combination with a special sequence in order to determine 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 greater than 10 (up to 70) and the root mean square deviation concerning the left to the right AIF can be decreased by factor greater than 5 (up to 30) if B_1 inhomogeneities are corrected. Also the deviations of the kinetic parameters K^{trans} and V_e obtained with the left and right AIF are significantly lower if B_1 correction is used.

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