Impact of the correction of B1 inhomogeneities for dynamic contrast-enhanced imaging at 3 Tesla

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Introduction: RF field inhomogeneities are a main source for image inhomogeneities and systematic errors in quantification of MRI data. The assessment of RF inhomogeneities becomes particular important for field strength above 1.5 T. This study characterized the influence of B_1 inhomogeneities for dynamic contrast-enhanced (DCE) MRI of the pelvis region at 3 T. For the DCE imaging a 3D FLASH sequence with a single-dose bolus injection of Magnevist was used. The active RF-field B_1 was measured with a pulse sequence originally proposed for optimizing flip angles during scanner preparation [1]. With this method the actual flip angle distribution can be determined in approximately one minute. In order to obtain the curves of the arterial input function and concentrations the temporal T_1 relaxation rate was calculated from the reference and contrast-enhanced images [2] and the results obtained with and without flip angle correction were compared.

Methods: The DCE imaging was performed using a 3D FLASH sequence with a single-dose bolus injection of 17 ml Magnevist (gadolinium-DTPA contrast agent, Berlex Schering AG, Berlin, Germany). Using $T_R/T_E = 3.34/1.1$ ms, flip angle = 15°, a 256 x 256 matrix and a 30 cm FOV, 4 mm-thick slices with no gaps, and 40 time points for 20 locations were acquired, totaling 800 images in about 4 min. The reference scan was performed with $T_R/T_E = 100/1.1$ ms and the flip angle = 5°. The matrix, the FOV, the slice-thickness and the locations of the sequence are the same as using for the DCE scan. The flip angle mapping (FAM) sequence is a stimulated echo sequence with three identical flip angles. The actual flip angle distribution, which is proportional to the active RF-field component B_1 is calculated from the ratio of the stimulated and the primary spin echo. The parameters of this sequence are: $T_R/T_E = 1200/14$ ms, a 52 x 64 matrix and a 250 x 308 mm FOV, 19 locations with 5 mm-thick slices and 10 mm gaps. Using the reference and the DCE images the T_1 relaxation can be calculated with Eq.1 [2]. $SI_{DCE}(t)$, α_{DCE} and T_{RDCE} are the signal intensity at the time point t the flip angle and the repetition time of the DCE scan respectively and the index $_{REF}$ characterises the parameters of the reference scan. The results obtained with eq. 1 were calculated once with the adjusted flip angles of the DCE and reference scan and once with the corrected flip angles using the FAM sequence. Because of the different location and resolution of the DCE and FAM scan it is essential to calculate the FAM scan with reference to the DCE scan by means of a 3D-interpolation method. In order to obtain concentrations in [mmol / l] eq. 2 is used, whereby $T_1(t)$ is the temporal longitudinal relaxation time, T_{10} is the relaxation time without contrast agent and r_1 is the relaxivity of Magnevist. All the measurements were performed on a 3 T System (Siemens Magnetom Trio a Tim System).

$$T_1(t) = -\frac{T_{RDCE}}{\ln\left(\frac{SI_{DCE}(t)}{SI_{REF}}\frac{\sin(\alpha_{REF})}{\sin(\alpha_{DCE})} - 1\right) - \ln\left(\frac{SI_{DCE}(t)}{SI_{REF}}\cos(\alpha_{DCE}) - 1\right)} \quad (1) \qquad c_{CM}(t) = \frac{T_{10} - T_1(t)}{T_1(t)T_{10}r_1} \quad (2)$$

Results: Fig.1 (a) shows the DCE scan for a selected slice. The depicted regions are used for the calculation of the required parameters and for the evaluation of the results with and without correction of the flip angle. Region 1 and region 2 are used to calculate the arterial input function (AIF). Region 3, region 4 and line 1 are in the space of one muscle tissue in order to point out the deviations of T_1 and concentrations within one selected tissue region. Fig.1 (b) shows the FAM scan for a selected slice. A value of 900 in the image corresponds to a flip angle of 90°. The calculated T_1-images with and without correction of the flip angle are depicted in fig.1 (c) and (d).
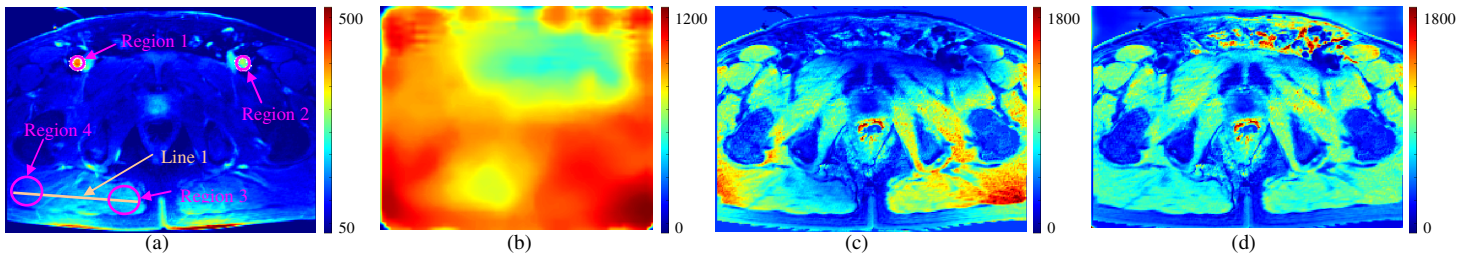

Fig. 1: (a) Perfusion scan with the respective regions, (b) FAM scan, (c,d) T1-image without/with flip angle correction

Fig. 2 (a) and (b) show the AIF in region 1 and region 2 respectively. The peak values without correction are about 70 % higher as the peak value with flip angle correction. Fig. 2 (c) shows the temporal course of the medial T_1-values in two different locations but within one tissue region. It can be seen, that the deviation of the curves without correction (blue, cyan) is about 6 times greater at the beginning and about 12 times greater at the end than the deviations of the curves obtained with flip angle correction. Fig. 2 (d) shows the local course of T_1 along the line 1 in a selected slice. Without flip angle correction the values of T_1 decrease from about 1500 ms to about 400 ms. With flip angle correction the results are considerably better.
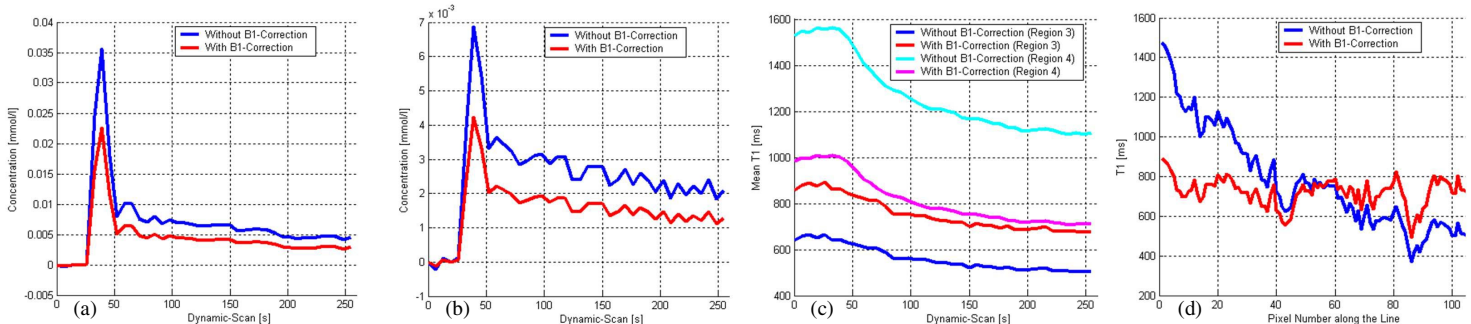

Fig. 2: (a,b) AIF in region 1 and 2, (c) Time dependent course of the medial T_1 in region 3 and 4, (d) Course of the local pixel values along Line 1

Discussion: Dynamic contrast-enhanced MRI was performed at 3 T in combination with a flip angle mapping sequence in order to determine B_1 inhomogenities. Using a reference scan the temporal T_1 relaxations, concentrations and the arterial input function were calculated and the results obtained without and with flip angle correction were compared. The peak of the arterial input function decreases of about 60 % if correction of the flip angle is considered. Moreover, with the flip angle correction the deviation of the temporal T_1-values at different locations but in the same tissue region decreases by a factor of more than 6 and also the variation of T_1-values inside a tissue region is significantly improved.

References: [1] W.H. Perman, Magn. Reson. Med. 9, 16-24 (1989), [2] Hittmair K, Gomiscek G, Magn. Reson. Med. 31, 567-571 (1994)