Arterial Input Partial Volume Artifacts Correction applied for a T1-weighted 3D Gradient Echo Sequence

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Purpose: To assess a method for voxel-based partial volume correction of the arterial input function (AIF) applied to DCE-MRI based on the methodology proposed by van Osch et al. in [1].

Material and Methods: Two different settings were carried out in a 1.5-Tesla-System (Magnetom Symphony, Siemens, Erlangen) using a Tim body coil as the receiver and Gadoteric acid as contrast agent (CA). The first experiment was performed in order to examine partial volume artifacts (PVA) in T2*-weighted 2D GRE DSC-MRI data (TR = 100 ms, TE = 5, 13.91, 17.98, 22.02, 26.04, 30.06 ms, flip angle α=20°, voxel size: 0.78125×10×0.78125 mm³, matrix size: 128×128, slice thickness: 10 mm, Field of View: 100 mm). The CA phantom consisted out of a test tube mounted in a rack, attached to MR device. MR-recordings were performed with seven different CA concentrations. We built up a static array and used Amira 5.2 (Mercury Computer Systems, Berlin, Germany) to convert statically data into simulated dynamics. Our second experiment examined PVAs in T1-weighted 3D GRE data collected under clinical conditions (TR=2.69 ms, TE=0.86 ms, flip angle α=30°, Voxel size: 2.85×4.5×2.85 mm³, Matrix: 160×48×128, slice thickness: 4.5mm, Field of View: 456×356 mm^2, time resolution: 1.26 s). PVAs were measured in sedated female pigs (weight: 45-65kg) at the femoral artery [3]. The spiral like trajectory of the complex blood signal was plotted in the complex plain (Fig. 1) and fitted by a logarithmic spiral function using two parameters to calculate the spiral center. The spiral was fitted with Matlab and an algorithm based on log-spiral characteristics. The logarithmic spiral had constant polar gradients, i.e. the spiral had the same cutting angle. Therefore, the geometric center calculation was based on constant heading change. Regions of full blood and contrast agent showed a signal with the spiral center close to the origin of the complex plane (Fig.1a). As partial volume voxels contain blood as well as tissue, PVA result in a spiral-center shift (Fig.1b).

Results: By evaluating the T2* 2D-GRE (CA phantom) data we were able to determine the complex trajectory center of full blood voxels in an area close to the complex origin. Furthermore, allocation of partial volume voxels to an area with greater center-origin distance was performed. For fit-evaluation the root mean square-value (rms) was used. Fits with too large rms were not involved. This permits to evaluate single voxels in relation to whether they include partial volume artifacts or not (Fig.1a/1b). Analyzing several regions of interest of data yielded center origin distances from -40 up to 40 signal units (su) with maximal signal contribution voxels (Fig.1a). Voxels in a statistically approved area outside of this range were allocated to partial volume artifact afflicted voxels (Fig. 1b). The data was distributed homogeneously around the origin. It was thereby possible to generate a stable method for quantifying partial volume artifacts in T2* 2D-GRE. Applying this method to DCE-MRI data, 70% of the fits had to be rejected. Therefore, the described procedure provides no reliable method for assessment of DCE-data. To assess the quality difference in application of the method to DCE and DSC-data, the phantom study was performed with a 2D-GRE sequence with different echo times. By analyzing the obtained TE data we determined a model by plotting the standard deviation (SD) against echo times. The standard deviation was used as an estimator of the impact of TE times on accuracy of the presented method for PVA quantification. Thereby, the most reliable echo times were found to be in a range of about 14 to 22 ms (Fig. 2). The blue vertical line represents the 3D-GRE TE and illustrates the data behavior. The result displays a strong correlation between echo time and accuracy of the analyzed data. Higher and also lower TE led to large SDs. The echo time of our 3D-GRE sequence was 0.86 ms. Based on the short echo time the signal has not enough time to evolve itself at DCE-MRI and as a consequence thereof especially the phase signal blurred. Too long echo times caused by signal-receiving durance also yielded an unreliable result because of the reduced absolute signal.

Conclusions: The presented study illustrates why measuring partial volume artifacts with an 3D-GRE (DCE-MRI) doesn‘t yield reliable results. The T2* 2D-GRE analysing method helps detecting and correcting partial volume artifacts that affect measurements of the arterial input function.

References: [1] van Osch et al. MRM, 49:1067-1076 (2003) [2] van Osch et al. MRM 45:477-485 (2001) [3] Sauerbrey et al. Biomed Res Int, 390506 (2014).

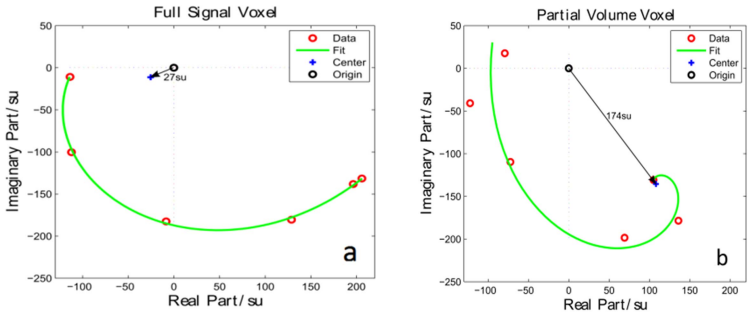

Fig.1: Logarithmic spiral fit in the complex plain for a single voxel (CA-Phantom). Voxel a) is of full blood type and has a center-origin distance of 27 signal units, at an echo time of 22 ms. In b) a partial volume voxel yielded a center-origin distance of 174 signal units using an echo time of 22 ms.

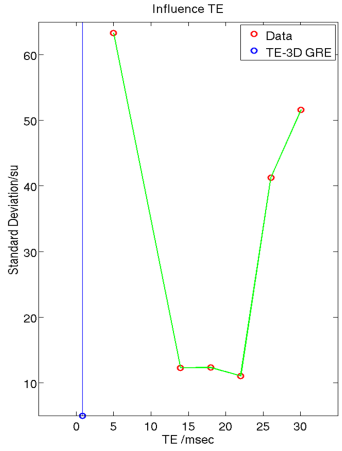

Figure 2: Influence of the Echo Time on analysis accuracy. Six echo times were analyzed using standard deviation (SD). SD is calculated separately for 20 voxels in the tubes centre.