Optimal location for phase-based arterial input function measurements near the MCA for DSC-perfusion MRI

E. J. Bleeker[1], M. A. van Buchem[1], and M. J. van Osch[1]
[1]Radiology, Leiden University Medical Center, Leiden, Netherlands

Introduction

Although phase is not frequently used for measuring the arterial input function (AIF) (a key element for quantification of the perfusion parameters CBF, CBV and MTT using DSC-MRI) phase does have several advantages over magnitude measurements: phase changes do not depend on the hematocrit resulting in a linear relation with Gd-DTPA, it has increased SNR and is very little affected by the contrast agent passing through tissue (1). Disadvantages are the sensitivity to motion induced phase shifts and the necessity for complex data acquisition. For determining the optimal location for phase-based AIF measurements near the MCA using single shot EPI, a numerical model was created and validated with phantom experiments.

Methods

The numerical model represents the MCA as an infinite cylinder with the magnetic susceptibility dependent on the Gd-DTPA concentration. The magnetic field changes in- and outside the cylinder were calculated using the Maxwell equations corrected for the Lorentz-sphere (2). The simulations were performed at a much higher resolution (250x250 μm^2) than is usually used in DSC-MRI measurements (2 mm^2 in-plane and 6 mm slices) and yielded the complex signal for different concentration contrast agent. Hereafter, dephasing and partial volume effects were included by regridding the high resolution representation to a voxel size comparable to clinical protocols. EPI image distortion (phase encoding only) were included in the model. Phantom experiments were performed on a 1.5 T Philips scanner using a standard quadrature head coil. The phantom filled with $MnCl_2$-doped water contained a tube through which $MnCl_2$-doped water was circulated. The tube was oriented perpendicular to the main magnetic field and the concentration of Gd-DTPA within the tube was increased in steps of 0.9 mM. Imaging parameters: single shot gradient echo EPI with TR/TE = 1500/41 ms; using 15 slices of 6 mm with 2.4x2.4 mm^2 zerofilled to 1.8x1.8 mm^2 voxels. The stack of slices was shifted in steps of 0.5 mm in the model and in steps of 1 mm in the phantom in order to study the influence of the vessel location in a voxel. To describe the in vivo situation more closely the tissue passage of the bolus was also added to the model. The $\Delta\varphi$ was calculated and unwrapped for every voxel of the simulation and compared with the input AIF (the ground truth). To evaluate the optimal location for AIF selection both the relative signal strength (a measure for SNR and accurate quantification) and the correlation (a measure for the shape) with the ground truth were calculated.

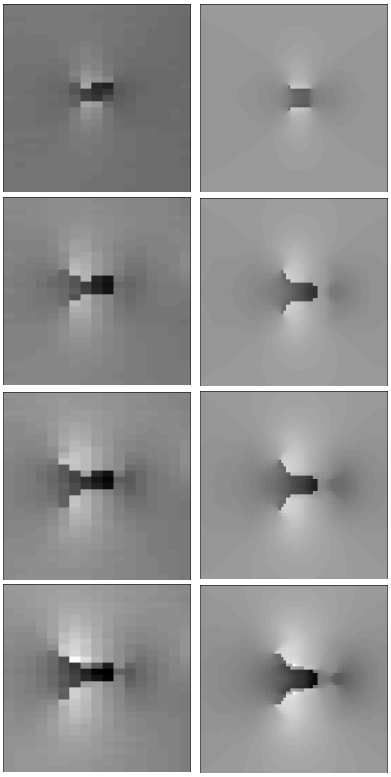

Figure 1: $\Delta\varphi$ images of phantom (left) and model (right) for 2.6, 6.1, 9.6, 13.2 mM Gd-DTPA.

In vivo model

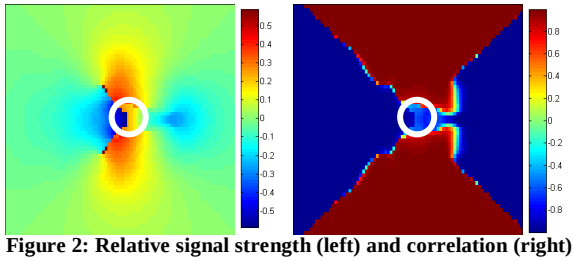

Figure 2: Relative signal strength (left) and correlation (right) with the ground truth for the in vivo model (circle indicates the vessel).

Optimal location for AIF

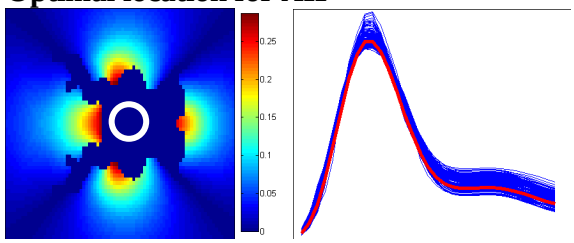

Figure 3: Relative signal strength (absolute values) with mask of correlation (ρ>0.995) (left) the variations in (normalized) AIF with the ground truth (red) (right).

Results

Figure 1 shows comparison of $\Delta\varphi$ images of phantom (left) and model (right) for 4 concentrations (2.6, 6.1, 9.6, 13.2 mM Gd-DTPA). Figure 2 shows the relative signal strength (left) and the correlation (right) with the ground truth for the in vivo model (FOV 30x30 mm^2). The correlation was thresholded to 0.995 and placed on top of the relative signal strength (see figure 3 left: absolute values). Figure 3 (right) shows all normalized measured AIF curves with a correlation of 0.995 or higher.

Discussion and conclusions

The numerical model was validated with a phantom experiment and showed good resemblance. Based on this model predictions were made for the optimal location for phase-based AIF selection in the vicinity of the MCA based on shape. The locations are 0.8 cm above, 0.8 cm beneath, 0.5 cm anterior and 0.8 cm posterior to the centre of the MCA or more peripheral. Beneath and anterior to the vessel are unusable locations for AIF selection for anatomical reasons.

References
1. M.S. Kotys JMRI 2007
2. E. M. Haacke Wiley 1999

Acknowledgements
This project has been made possible by a grant of the Dutch Technology Foundation STW (grant 7291)