Dephasing around variably shaped arteries: Simulations and in vivo data

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Introduction:

Dynamic susceptibility contrast (DSC) MRI is a widely used imaging technique to obtain the current state of cerebral hemodynamics. Fast T_2*-weighted echo planar sequences are commonly used, however, in these sequences partial volume effects distort the signal originating from the arteries and thus limit the ability to quantify perfusion parameters. Therefore, the influence of vessel size and orientation on the arterial input function (AIF) is of interest [1]. So far, only for the special case of a vessel aligned with the main magnetic field, partial volume effects are quantifiable [2]. In this work, individual vessel geometries were used to model the signal in different voxels of each subject. The vessel structure – being the basis of the model – was extracted from a time-to-flight MR angiography. We adopted previously published susceptibility data of Gd-DTPA in blood as well as theoretical works about frequency shifts in the surroundings of blood vessels.
Here we demonstrate a good agreement between the theoretically calculated signal maps and in vivo data.

Methods

Image data from MR angiography are resliced with respect to the DSC-MRI dataset. Therefore, a grid for simulation was defined with a much higher resolution. Further a clustering algorithm is applied to eliminate noise from the angiographic data. In a next step all vessels are decomposed in subvoxels which will described as small sources of magnetic field inhomogeneities. In this work, analytical solutions for the frequency shift in the surroundings of a sphere are used [3]. The direction of the main magnetic field B_0 during measurement was also taken into account. The inner volume of the vessels is modelled with quadric signal and linear phase dependencies [2]. Finally, the signals of all subvoxels are integrated and summarized to achieve the modelled signal of a voxel in DSC-MRI. To test the simulations in vivo data were measured using the following protocol: DSC-MRI: gradient echo EPI, TE 54 ms, TR 1.3s, 6mm slice thickness, 1.8mm pixel spacing, 20ml 0.5 mM Gd-DTPA + 20ml saline flush, 4ml/s injection speed; MR angiography: time-of-flight, TE 6.5ms, 0.9mm slice thickness, 0.4mm pixel spacing.

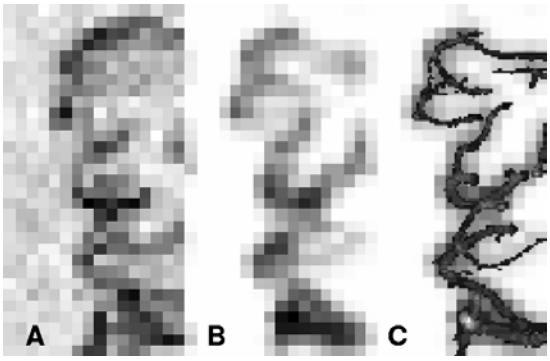

Figure 1

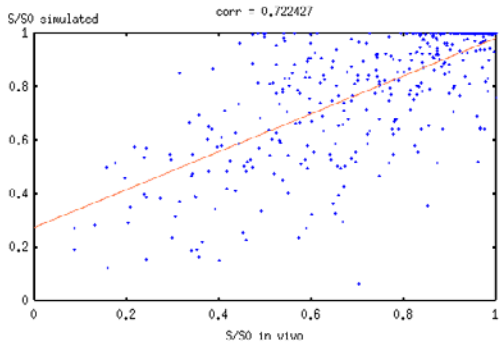

Figure 2

Results and Discussion

Figure 1 exemplarily shows data from a single subject. In Figure 1A the signal decrease is seen when the contrast agent reaches the arteries. Figure 1B presents the same parameter but now simulated. All calculations were based on geometric information as shown in Figure 1C. Figure 2 plots over the relative signal decrease in vivo the results obtained from the simulation. Despite the complex shaped arteries, a relatively high correlation was observed.
DSC approaches have been widely utilized in the study of tissue perfusion and are of high clinical importance, e.g. in stroke and inflammatory brain diseases [4]. So far, most studies present relative or estimated perfusion parameters only. Multiple problems are still associated with quantifying DSC-MRI data, besides rapid progress in acquisition techniques, partial volume corrections schemes or theoretical approaches in AIF modelling [1, 2, 5]. A major draw-back for the quantification of human data is to be found in the anatomical diversity of blood vessels *in vivo*, which is not sufficiently reflected in simplified cylinder models. Due to the fact that arteries were generally not aligned with the main magnetic field, the observed as well as the calculated dephasing in the surroundings is not negligible. We here demonstrate in simulations and in patient data that the implementation of structural information derived from angiographic MRI data into AIF modelling is a robust and reproducible method, that will enables us to reliably quantify absolute perfusion parameters in future studies.

References

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