Evaluation of signal formation in local arterial input function measurements of DSC-MRI

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Introduction

Local or regional arterial input function (AIF, the evolution of the concentration of contrast agent in a brain-feeding artery) measurements aim for voxel specific AIFs from small arteries. These local AIFs are assumed to reflect the true input of the microvasculature much better than global AIFs. However, *do the measured local AIFs reflect the true concentration-time curve of small arteries?* Partial volume effects (PVEs), which arise from the relatively low spatial resolution used in dynamic susceptibility contrast (DSC) MRI, often hamper the selection of the AIF. PVEs have been shown previously to lead to shape changes in the AIF (1-3). The aim of this study was to investigate whether automatic local AIF measurements would reflect the true concentration-time curve (CTC) of small brain-feeding arteries. For this purpose, a 3D numerical model was created that simulates local AIF measurements with single shot EPI and PRESTO acquisition at different orientations and with different artery sizes. In addition, in vivo data were used to identify true local AIF candidates using two different angiograms and the shape-characteristics from these candidates were compared to gray matter CTC shape-characteristics.

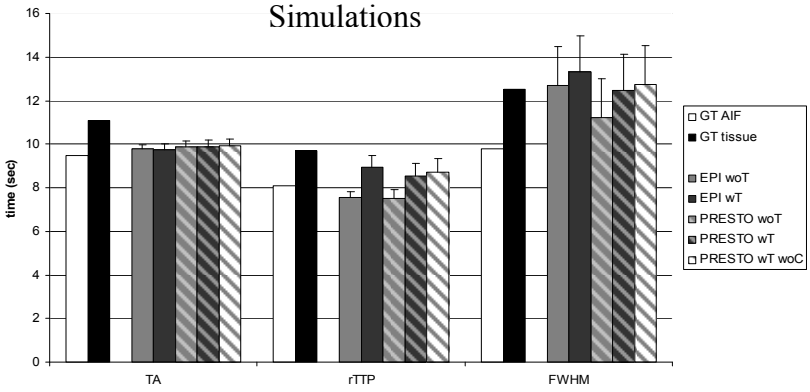

Figure 1: Three timing characteristics (TA, rTTP and FWHM) in seconds to compare the simulated local AIFs (of single shot EPI and PRESTO) with the ground truth AIF (white bar) and ground truth tissue response (black bar). Without tissue response (woT), with tissue response (wT) and without crushing (woC).

Methods

Local AIF measurements were investigated using simulations (implemented in MATLAB) and in vivo examples (five DSC-MRI exams of patients suffering from arteriovenous malformations; 3T (Achieva, Philips, the Netherlands) using PRESTO (TE\TR 30\20 ms), flip angle 8º, voxel size 1.9x1.9x3.5 mm^3). The models simulated EPI and PRESTO acquisition with and without tissue response in the surrounding of the small artery and for PRESTO the effects of the large gradients that crush the intravascular signal were investigated. Evaluation of the partial volume effects are based on the changes in time of arrival (TA), relative time to peak (rTTP) and full width at half maximum (FWHM). Local AIF candidates in vivo were determined using two different angiograms: time of flight (0.35x0.35x0.6 mm^3) and subtraction of pre- and postcontrast 3D-T_1 (0.86x0.86x1.2 mm^3) scans. Since the ground truth is unknown in vivo, we used the gray matter (GM) responses for comparison of the shape characteristics (TA, rTTP and FWHM) of the local AIF candidates.

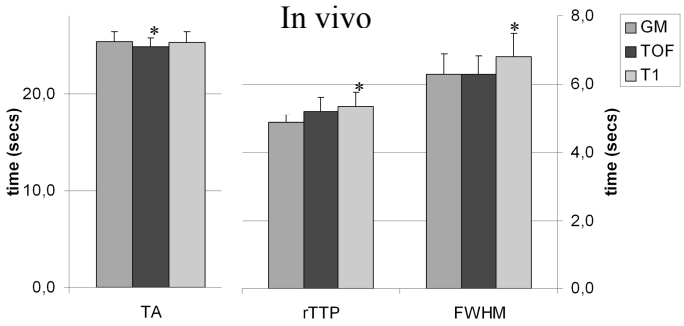

Figure 2: Shown are three timing characteristics (time of arrival (TA), relative time to peak (rTTP) and full-width-at-half-maximum (FWHM)) of the in vivo local AIF candidates (TOF-based and T_1-based) together with GM metric values. (*) is significant difference compared to GM ($p<0.05$).

Results

Simulations showed (see Fig 1) that including the tissue response (wT) in the simulations did not significantly delay TA for the two investigated sequences. The addition of the tissue response in the local AIF voxel does, however, increase the rTTP for both sequences. The FWHM of the simulations is larger than the FWHM of the ground truth AIF and close to the FWHM of the ground truth of the tissue response.

The in vivo data showed (see Fig 2) that GM has the latest TA but the value is very close to the TA of the T_1-based local AIF candidates. The TA of the TOF-based local AIF candidates are significantly lower than GM and significantly lower than the T_1-based local AIF candidates. The average rTTP of the TOF-based local AIF candidates is larger than the rTTP of gray matter although not significantly, whereas the average rTTP of the T_1-based local AIF candidates is significantly larger than the average rTTP of gray matter. The TOF-based local AIF candidates have ΔR_2^* profiles as broad as GM, as measured with the average FWHM. The T_1-based local AIF candidates have a significantly larger FWHM than the average FWHM of GM.

Discussion and conclusions

The findings are two-fold. First, the simulations show that PVEs in the local AIF measurements lead to broader CTCs than the ground truth AIF due to extravascular susceptibility effects and the contrast agent passing through surrounding microvasculature. This adds to the findings of a previous study by Kjolby et al. (1) that primarily focused on the tissue passage as an explanation of the broadening of the AIF near a large artery. Second, the in vivo data showed that the shape-characteristics of local AIFs are similar to the shape-characteristics of gray matter CTCs. These findings suggest that local AIF measurements do not reflect the true CTC in small arteries.

References 1) Kjolby MRM 2009;61(6):1300-9 2) van Osch jMRI 2005;22(6):704-9 3) Bleeker jCBFM 2009;29(4):840-52