Alternative Sequence for Arterial Input Function Measurements for Bolus Tracking Perfusion Imaging in the Brain

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TARGET AUDIENCE: Developers of methodology for perfusion measurements, clinicians searching for advanced methods of DSC MRI.

PURPOSE: We recently presented a method for a quantitative determination of the arterial input function (AIF) in the carotid arteries[1]. The AIF-measurement plug-in in the standard DSC perfusion sequence was optimised for high doses of contrast achievable in animal experiments. In the present work, we propose an alternative AIF measurement plug-in for low-dose clinical measurements and present a comparative discussion of both methods.

METHODS: When measuring the concentration of paramagnetic tracer in arteries, the following problems are encountered: (i) The presence of contrast agent results in a significant shortening of blood T2*, which renders the signal invisible at echo times optimised for tissue contrast (~30ms); (ii) An apparent shift of large vessels ("phase-shift artefact") due to a tracer-induced Larmor frequency shift; (iii) Partial volume effects.

In our previous work, we tackled these problems within the following principles: Measurement at the carotid arteries with very short echo times (~1ms), one-dimensional (1D) projection imaging with high spatial resolution, and background saturation using inversion recovery. The phase shift artefact was used for the good to quantify the contrast agent concentration. This approach worked very well for measurements in pigs. In patients, the lower contrast agent dose (0.1 mmol/Kg body weight single dose) leads to smaller peak concentrations (~10mmol/L), which makes the phase arterial shift less pronounced thus decreasing the accuracy of AIF quantification.

On the other hand, the lower contrast concentration allows for an extended echo time on the order of TE=10ms. After this time span, the frequency shift manifests itself in a phase shift, which can be detected robustly as for "phase-AIFs" [2,3]. Hence, both frequency and phase shift can be used. For this pilot study, we modified our sequence[1] by imaging a slice at the neck using two dimensional EPI in combination with a dedicated saturation pulse.

(A male patient (73Y, 70Kg) with a suspected brain tumour was measured in a 3T Siemens TIM TRIO scanner after injection of 14 mL of 0.5mol/L Gadobenate contrast agent (Multihance®, Bracco, Italy) at the rate 3 mL/s. TR/TE = 150/13ms, 6/8 partial Fourier, resolution 2.66×2.66×4 mm^3.

RESULTS: The neck slice is shown in Fig.1 for the first scan and in the steady state, where background is efficiently suppressed. The time series of the signal phase in a ROI around the right artery (red) and a vein (blue) is shown in Fig. 2 in units of the corresponding frequency shift (13 Hz/mM).

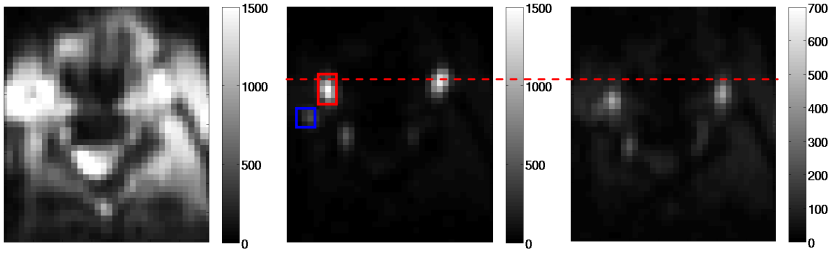

Fig 1: Magnitude images at time frame 1, 7, and 237 (bolus passage). The background visible in the first scan is efficiently suppressed in the steady state. During bolus passage the arteries are apparently shifted (red line as a reference).

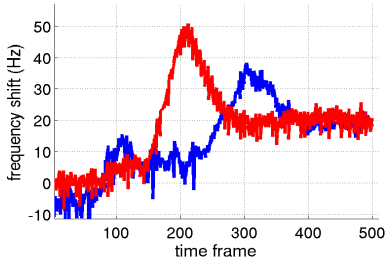

Fig 2: Phase-based AIF (red) and venous output function (VOF, blue) from a ROI around the right carotid artery and vein. The increase prior to bolus arrival might result from slight patient movement, swallowing, or retrograde flux into cervical veins.

DISCUSSION: We demonstrate that the combination of the suppression scheme proposed in our earlier work[1] with EPI enables imaging of isolated vessels in the neck for determination of phase based AIFs. The advantage over 1D projection imaging is an improved elimination of partial volume effects and the possibility of evaluating all arteries in the slice. Measurement of the venous output function can yield further valuable information for perfusion evaluation. In previous works on phase based AIFs[2,3], the apparent shift of the artery during bolus passage was not taken into account. The absence of partial volume effects in our approach allows for consideration of the frequency shift by evaluation of a region around the artery, or by tracking the apparent vessel shift in the image. The currently used approaches of phase-based AIF have a disadvantage in comparison with the determination based on the frequency shift[1]: The evaluation is built on the phase at one single point (TE) thus requiring a normalisation on a baseline. Measuring the phase at an additional reference point, e.g. by an acquisition scheme which starts at the centre of k-space and returns to it at TE, could help correcting for any phase changes not induced by the contrast agent. Note that both the short repetition times at the neck slice and the background suppression in our framework[1] are crucial in order to resolve the cardiac cycle and eliminate partial volume effects.

CONCLUSIONS: We demonstrate the feasibility of AIF measurement with EPI in a neck slice as an extension of our previously described framework[1]. This implementation is more suitable for clinical measurements with a single dose of contrast agent. In contrast, the previous method based on the frequency shift is superior for higher doses, higher main fields and for tracers with a higher magnetisation such as iron–based substances. The developed method is open for optimisation, additional modifications of the readout scheme as spiral k-space sampling, compressed sensing and k-t grappa can help improve the measurement accuracy and will be addressed in future works.

References: 1. Kellner E et al. Arterial input function measurements for bolus tracking perfusion imaging in the brain. MRM 2012;DOI: 10.1002/mrm.24319 **2.** Van Osch M J et al. Measuring the arterial input function with gradient echo sequences. *MRM* 2003;49:1067 **3.** Conturo T E et al. MR imaging of cerebral perfusion by phase-angle reconstruction of bolus paramagnetic-induced frequency shifts. *MRM* 1992;27