Measurement Sequence for Quantitative Phase-Based Arterial Input Function for Bolus Tracking Perfusion Imaging

Elias Kellner[1], Irina Mader[2], and Valerij G Kiselev[1]

[1]Medical Physics, University Medical Cener Freiburg, Freiburg, Germany, [2]Section of Neuroradiology, Neurocenter, University Medical Center Freiburg, Freiburg, Germany

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

PURPOSE: To examine the feasibility of measuring quantitative phase-based arterial input and venous output functions in an additional slice crossing the carotid arteries, with measurement parameters optimised for blood and to investigate the optimal location for the measurement slice.

INTRODUCTION: It is known, that phase-based[1,2] arterial input functions (AIF) offer a better contrast-to-noise ratio and rely on a linear relation between the phase and the contrast agent concentration in blood as opposed to methods based on the relaxation rate. We recently presented a method for a quantitative determination of the arterial input function, which combines the phase-based approach with a measurement optimised for the blood signal[3]. The method is based on measuring the carotid arteries in an additional slice in between each slice measurment of the brain. Using a very short echo time resolves the problem of signal voids due to the strong contrast-agent induced dephasing in blood. Partial volume effects are minimised with a suppression of the background signal with short repetition times at the AIF slice, and an inversion pulse. In the present work, we investigate the optimal location for the AIF measurement at the carotids, and present results using the 2D-EPI phase-based version of the proposed framework with a simplified background suppression based on short repetition times only.

METHODS: Two patients were measured (P1: 21Y, male, 130Kg, suspected brain tumour and P2: 24Y, female, 64Kg, suspected inflammatory disease) in a 3T Siemens TIM TRIO scanner. Injection consisted of 15 / 12 mL of 0.5mol/L Gadobenate contrast agent (Multihance®, Bracco, Italy) at the rate 3 mL/s. Written informed consent was obtained. The first measurement aimed at investigating the optimal location for the AIF slice. As a simple approach, a gradient echo EPI, which is normally used for the perfusion measurement in the brain, was positioned at the neck with 3 slices only. Background signal was suppressed using a short TR of 96 ms. The three slices were positioned (1) at the arteria carotis communis antecedent to the bifurcation, (2) directly at the bifurcation, and (3) subsequent to the bifurcation at the ICA. TR/TE = 96/8.7ms, 6/8 partial Fourier, resolution 3.2x3.2x5 mm³. Several regions were drawn manually around arteries and veins to measure arterial input functions and venous output functions (VOF).

In the second measurement, a gradient-and-spin-echo perfusion sequence was extended with a 2D-EPI readout of the neck slice in between each slice of the brain measurement. Background signal was suppressed with the TR of 150ms. Parameters for the brain measurement were 11 slices, TR/TE = 1660/21ms, 6/8 partial Fourier, resolution 2.5.x2.5x5 mm³. AIF slice: TR/TE=150/8.8ms, 6/8 partial Fourier, resolution 3.2.x3.2x5 mm³. CBF and CBV maps were calculated from a manually selected AIF using Tikhonov deconvolution.

RESULTS: The arterial ROIs selected in P1 and their signals are shown in Fig. 1. Apparently, the signal is much better above the bifurcation, and not usable below. In Fig. 2, the upper slice is used for a detailed evaluation. The signal of both, the left and right ICAs and vertebral venous plexus are shown. The time courses of the phase of the signal are almost identical at both sides. The signal magnitude shows a much greater variability.

The results of the measurement in P2 are shown in Fig. 3. The method allows for quantitative determination of the AIF and venous output function, from which quantitative perfusion maps can be calculated. The whole brain mean values are CBF = 38 mL/100g/min and CBV = 1.7%.
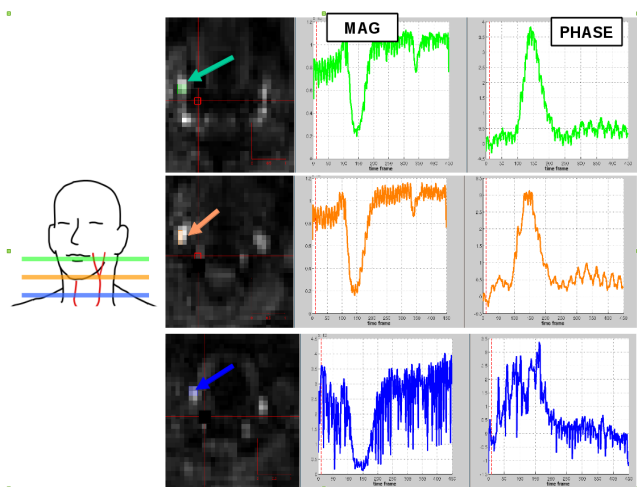

Fig 1: Patient 1 Time course of the signal in the ICA at three different locations posterior and anterior to the carotid bifurcation. The signal in the upper slice shows the best quality.
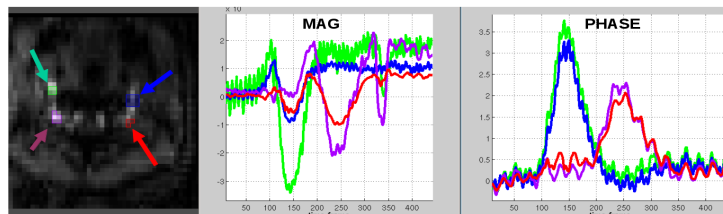

Fig 2: Patient 1 Arterial input functions and venous output functions at different positions in the uppe slice. The functions are very similar at both sides.
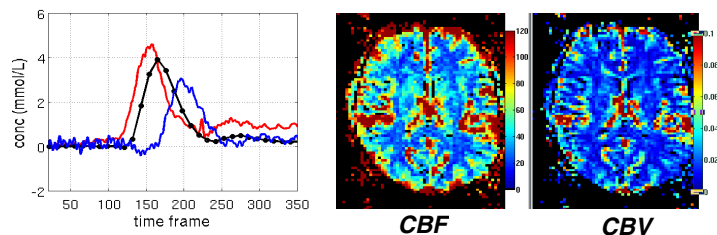

Fig 3: Patient 2 AIF (red) VOF (blue) and mean tissue curve of a white matter ROI (black). With the quantitative AIF, quantitative CBF and CBV maps can be calculated.

DISCUSSION: The comparison of three AIF slices indicates that the optimal location for the AIF measurement is above the carotid bifurcation. A detailed inspection of different vessels in the upper slice confirms that phase-based evaluation is much more reliable than using the magnitude of the signal. Further, the AIFs measured at different vessels are very similar, which confirms the robustness of the method. Third, the presented framework allows for the determination of the venous output function (VOF), which can yield further valuable information for perfusion evaluation.

The result obtained in P2 demonstrates the feasibility of the AIF-determination in the framework of conventional perfusion measurement. Further optimisation is necessary to enable an automated selection of the AIFs. A theoretical limitation might be that the position of vessels is apparently shifted during the bolus passage due to the phase shift artifact. Hence, mutual influences of arteries and veins are possible.

CONCLUSIONS: We demonstrate that the optimal location for the proposed AIF measurements is above the carotid bifurcation. A pilot measurement with this method yields a quantitative arterial input function and venous output function, from which quantitative perfusion maps can be calculated. Further optimisation is necessary for the routine clinical applicability of the method.

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