Arterial Input Function for Bolus Tracking Perfusion Imaging in the Brain

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Introduction: In this study, we propose a solution to the yet unresolved problem of dynamic susceptibility contrast MRI (DSC-MRI), the measurement of the AIF. In contrast to the measurement in the brain, the signal during the tracer passage in a feeding artery is difficult to quantify due to the following problems. (i) The presence of contrast agent results in a significant shortening of blood T2 (T2 = 2ms at 3T for the tracer concentration of 15 mmol/L), which renders the blood signal invisible. This is much shorter than the echo time around 30ms, which is close to optimal for tissue contrast. The signal void in blood weakens another problem, which is (ii) an apparent shift of large vessels in images acquired with fast imaging techniques. This shift arises from the varying Larmor frequency in blood during the passage of paramagnetic tracer. (iii) Partial volume effect is also a top problem in the AIF measurements. In this work, we propose the following approach to solve the problems: The AIF is measured at the carotid arteries by acquiring an additional one-dimensional projection image of a slice in the neck in between each slice of the EPI measurement in the brain. The arteries are singled out on the background by saturating the latter using inversion recovery. The apparent shift in position of the arteries originating from the change in Larmor frequency induced by contrast agent is linear [1] and can be used for quantification of the contrast agent concentration.

Methods: The sequence was implemented on a 3T scanner (Siemens, Germany). 25 ml of 0.5mol/l Gd-DTPA contrast agent (Multihance, Bracco, Italy) was delivered to the animals at a rate of 5ml/s followed by a 30ml saline flush. EPI parameters were TE_GE/TE_SE/TR=20/86/1590ms, 9 slices, resolution 2.62x2.62mm. Parameters for the AIF slice as denoted in Fig. 1 were pulse length 740ms, readout gradient strength 900uT/m, TR=176ms, bandwidth 38.2 Hz/mm. The sequence was tested on an animal model (9 pigs).

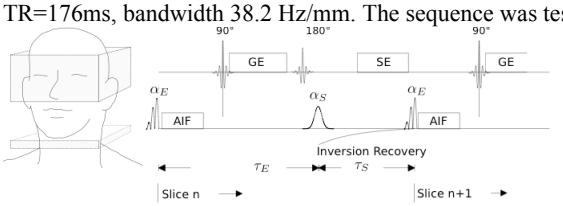

Fig.1

Lorentzian functions were fitted to the aqcuired spectra for each time frame in order to obtain the contrast induced frequency shift, and thus the AIF (Fig. 2). Grey and white matter masks were automatically segmented with spm8 [2] using T1 weighted images. The Stewart-Hamilton formula states that the cardic output (CO) equals the amount of injected tracer, devided by the integral over the tracer concentration time course anywhere in the vascular system. CO values are calculated using the obtained AIFs.

Results: Fig. 2 shows a section of measured spectra of the left carotid artery from an animal. The pulsating arteries are clearly visible above the background. The AIF fit is shown in black. Table 1. shows the calculated cerebral blood flow (CBV) and the cardiac output (CO). Fig. 3 demonstrates the comparison of AIFs as in Fig. 2 (red) with automatically selected AIFs using cluster analysis [3] applied to the gradient echo images of the brain (black). Automatically selected AIFs are scaled with a common factor for all pigs. The AIF found with the presented method is quantitative, narrower, higher sampled and shows a lower group variability (The standard deviation in peak maxima is 8.8% for the new method, and 32% for the automatically selected AIF).

Discussion and conclusions: We present a trully quantitative determination of arterial input function for DSC MRI, which is for the first time compatible with the clinical demands, especially at high magnetic fields strengths. The results of the first test in an animal model reproduce known values of the cardiac output and the cerebral blood volume. Determination of cerebral blood flow will be reported elsewhere.

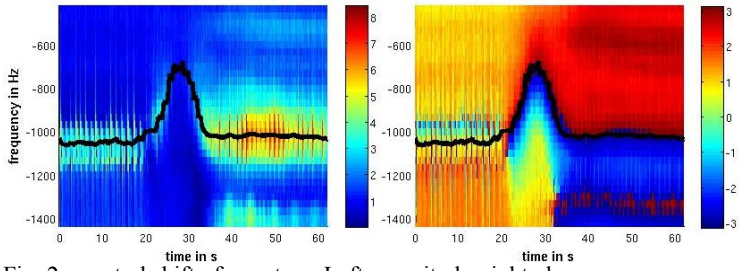

Fig. 2: spectral shift of an artery. Left magnitude, right phase

	P1	P2	P3	P4	P5	P6	P7	P8	P9	MEAN	STD
GM(%)	3.0	3.3	3.1	2.7	2.7	2.6	2.2	2.2	2.4	2.7	± 0.4
WM(%)	1.6	2.2	1.7	1.6	1.5	1.8	1.3	1.3	1.4	1.6	± 0.3
CO(L/min)	3.8	3.5	4.7	3.5	3.4	4.0	3.3	5.3	4.8	4.0	± 0.7

Table 1

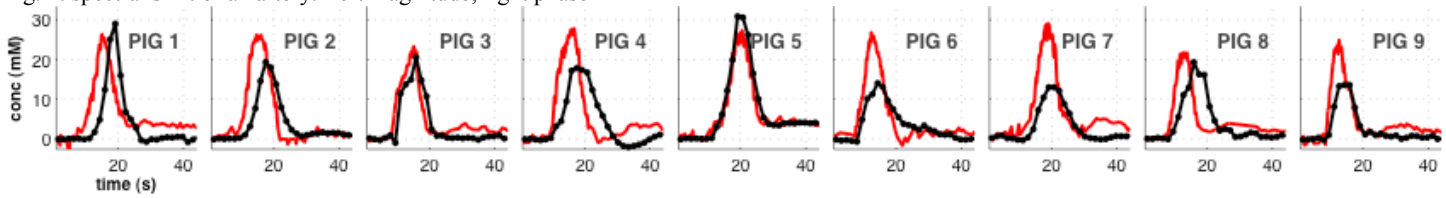

Fig. 3

[1] M.J. van Osch, E.J. Vonken, M.A. Viergever, J. van der Grond, and C.J. Bakker. Measuring the arterial input function with gradient echo sequences. Magn Reson Med., 49:1067{76, 2003. [2] SPM8, statistical parametrical mapping, http://www.fil.ion.ucl.ac.uk/spm/ [3] Kim Mouridsen, Soren Christensen, Louise Gyldensted, and Leif Ostergaard. Automatic selection of arterial input function using cluster analysis. Magn Reson Med, 55(3):524{531, 2006.