A perfusion phantom for the validation of arterial spin labeling measurements

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INTRODUCTION

Pulsed arterial spin labeling techniques (1) have the ability to measure perfusion without additional application of contrast agent. Intrinsic water molecules in arterial blood are used as a freely diffusible contrast agent. Using FAIR technique (2), inversion recovery images with a nonselective inversion pulse are subtracted from images with a slice-selective inversion pulse. The difference signal is proportional to relative perfusion. A general kinetic model (3) provides a theory to calculate the absolute perfusion using arterial spin labeling (ASL) techniques.

The aim of this work was to validate the general kinetic model using a perfusion phantom. In this highly porous polymer, water is used as perfusate. The absolute phantom water flow (PhWF, equivalent to CBF) can be accurately calculated from the amount of water per time unit delivered by the hose pump. Using ASL combined with FAIR technique, PhWF is determined according to the general kinetic model.

THEORY AND METHODS

The difference signal ΔM(t) can be described according to the general kinetic model (3):

$\Delta M(t) = 0 \qquad t<\Delta t \qquad [1]$

$\Delta M(t) = 2 \cdot M_0 \cdot f \cdot (t-\Delta t) \cdot \exp(-t/T1) \cdot q \qquad t>\Delta t \qquad [2]$

M_0 : fully relaxed magnetization of perfusate, f: CBF [ml of perfusate/ml of voxel volume/second], Δt: transit-delay, T1: T1-relaxation of the perfusate, q: correction term.

The perfusion phantom (Fig.1) consists of a cylindrical acrylic glass body (r=2.5cm, l=10cm). The highly porous polymer (r=2.4cm, l=0.8cm, 10µm pore-size) is mounted between two cone-shaped insertions for flowing to and draining off water. The perfusate circulation was driven by a hose pump. The absolute flow was quantified by a measuring cup.

Measurements were performed on a 1.5 T Symphony System (Siemens Erlangen, Germany). A FAIR tagging-scheme with C-FOCI-pulses (duration 10.24ms, β=1300, µ=6, RF-bandwidth=2482Hz) was implemented. Readout-slice thickness was set to 5mm, the slice-selective FAIR tagging slab covered 10mm. Inversion time TI was varied from 100ms to 5000ms to measure the complete inflowing perfusate bolus. Five averages of slice-selective and nonselective IR-images were acquired. The delay time between each image acquisition was set to 15s. Image acquisition was performed using TrueFISP techique with the parameters TR=4.08ms, α=70° and FOV=240x240mm^2 with 128x128 matrix size.

RESULTS

Determing flow with the measuring cup, the absolute PhWF in the perfusion phantom was PhWF = (0.86 ± 0.01)ml/s·ml. Fig. 2 shows the measured difference signal and the fitted curve using equitations [1, 2]. The fit-algorithm calculated a PhWF = (0.91 ± 0.06) ml/s·ml.

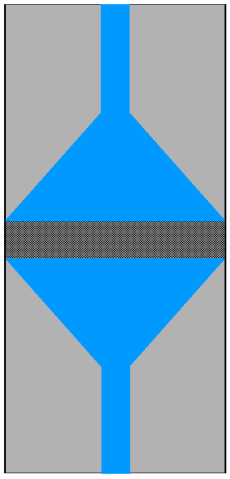

Fig.1: Scheme of the perfusion phantom with polymer (black), perfusate circulation (blue) and phantom body (grey)

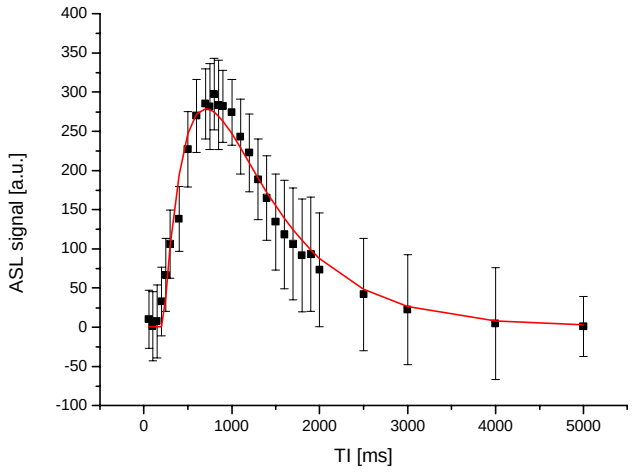

Fig.2: Measured ASL- signal (black) and fitted curve (red).

DISCUSSION AND CONCLUSION

The fitted curve is in good agreement with the measured difference signal. The absolute perfusion which was measured using ASL is in good agreement with the absolute perfusion in the polymer. The calculated perfusion is inversely proportional to the fully relaxed magnetization of perfusate (M_0), which has to be determined accurately.

The fit-algorithm is highly sensitive to variances in the transit-delay Δt. Since the Q2TIPS-technique [4] is providing a method to determine absolute perfusion without the accurate knowledge of Δt, this technique should be applied to the perfusion phantom. The perfusion phantom is a suitable tool for the validation of ASL-techniques and in future work other perfusion quantification techniques like T2*- weighted dynamic MRI will be tested.

REFERENCES

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