Dispersion of a short ASL bolus along the arterial tree

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Introduction: In ASL, the inflow of labeled blood is usually modeled by assuming a single arrival time of the bolus in the voxel under consideration. This is equivalent with the assumption of plug-flow. In 2004, Hrabe et al [1] published a model, which considered a Gaussian distribution of bolus arrival times. The effects of dispersion of blood flow was modeled and examined in detail in recent publications [2, 3]. It was found that accurately modeling flow dispersion is complicated mainly due to pulsatility and vessel branching.
This work focuses on measuring and visualizing how a short labeled blood bolus is blurred and dispersed while moving down the arterial tree. By doing this, more accurate estimates can be provided for ASL models, which include dispersion.

Methods: A single-shot 3D-GRASE sequence [4] was used for image readout (26 slices, resolution 5×5×4mm^3, acquisition time 340ms, TE 18 ms, centric reordered, TR 3300ms) at a 3T scanner (Magnetom Trio, Siemens, Erlangen). A time series was acquired with 28 time steps starting at TI=300ms with an increment of 100 ms. No repetitions were used, thus, a total scan time of 2:58min was achieved. A constant bolus length of 500ms was used. The well-known ASL model according to the general kinetic model by Buxton [5] was used with the bolus length as an additional free parameter. Nonlinear parameter fitting (simplex algorithm) was used to estimate the local bolus length for each voxel. Bolus length was drawn against bolus arrival time. Slight smoothing was applied on the time axis (σ = 100 ms, similar to temporal resolution)

Results: Figure 1 shows five time curves measured at different positions along the arterial tree. The first curve was acquired in the internal cerebral artery (ICA) right before entering the circle of Willis. The three curves in the middle were acquired at different positions within the anterior cerebral artery (ACA) and the right curve represents tissue curve close to the ACA. A clear evolution of the curve caused by dispersion is seen.

Discussion and Conclusions: Although not new, this work presents a feasible way to use localized dispersion measurements in a clinical setting. One important feature is the short bolus to start with, since only with this defined starting point dispersion along the arterial tree can be measured.
This work does not consider cardiac pulsation. Wu et al [2] have shown that the amount of dispersion depends on the phase within the cardiac cycle. Thus, for a more complete analysis cardiac pulsation has to be included. Nonetheless, the data impressively shows how a relatively sharp bolus in the middle cerebral artery is blurred and dispersed while traveling through the arterial tree. More specificity could also be achieved by flow-sensitive gradient pulses. However, this might be tricky since only spins above a certain threshold would be affected, which could deform the measured bolus shape. Directly measuring dispersion along the arterial tree can provide useful information for better modeling ASL signal behavior under consideration of dispersion effects. In general, local dispersion patterns, as demonstrated here, might be a sensitive tool to detect changes in haemodynamics, which could origin from small vessel and neuro-degenerative diseases.

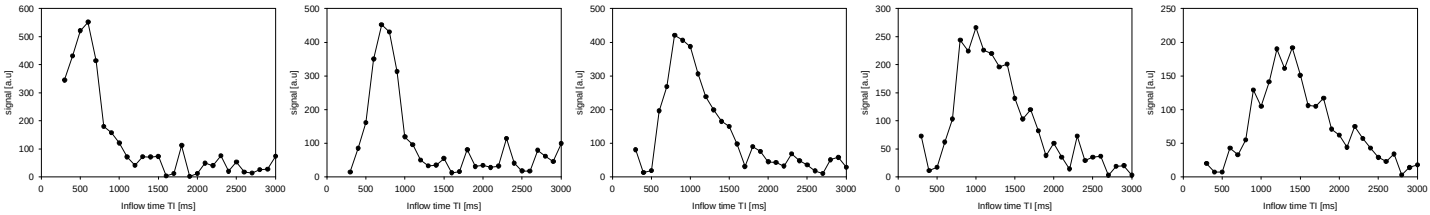

Fig. 1: Bolus shapes at different levels of the arterial tree. The left curve was acquired in the ICA right before entering the circle of Willis. The three curves in the middle were acquired at different positions within the ACA and the right curve represents tissue curve close to the ACA.

References:

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