INTRODUCTION: Obtaining quantitative cerebral blood flow (CBF) using non-invasive arterial spin labeling (ASL) techniques is challenging due to uncertainties in bolus arrival time, arterial-input-function (AIF), underlying kinetics and static tissue parameters. In this work, we focus on the effects from the shape and length of the AIF on CBF quantification. Traditionally, when quantifying pulsed ASL, the bolus is assumed a boxcar-function only undergoing T1 decay before it reaches the exchange site. However, bolus dispersion will be present and differences in vessels sizes, length and tortuosity will result in dispersion differences, not only in between subjects, but also across the brain [1]. Generally, the bolus length is often expected to be well defined using QUIPSS II type of approaches [2], where the end of the bolus is cut off at a predefined time. However, from ultra sound studies it is known that large variability in blood velocities exist in brain arteries (65±19cm/s in distal ICA) [3] and here and how wide the label slab has been defined, the blood may have left the label region at typical cut-off times of 0.6-0.8s.

Here the aim was to show the variability in dispersion and bolus duration, based on data acquired as part of the worldwide test-retest “The QUASAR reproducibility study” [4]. Quantification errors using standard models are simulated for AIF variations within normal ranges of velocities and dispersion.

METHODS: The results from the QUASAR reproducibility study consist of data from 28 sites and 284 (164 Male, 120 Female, 34±9 years) healthy volunteers. All subjects gave written informed consent before participation according to local ethics regulations and underwent 4 ASL scans in two sessions separated by an average of two weeks (13±3 sites). All sites were equipped with 3T Philips Achieva whole body systems with automatic planning capabilities, which was used for automatic slice repositioning between sessions. The QUASAR experiment is based on multi-slice acquisition at multiple inversion time-points [5]. General scan parameters were: TR/TE/TI/H=4000/23/300/40 ms, 0.64s QUIPSS II bolus length, 64x64 matrix, 7 slices, FOV=240x240, flip-angle=35/11.7°, SENSE=2.5. Venc=[4, 4 cm/s], 84 (48 @ Venc=4cm/s, 24 @ Venc=infinity, 12 low flip angle) averages, all implemented in a single sequence. The QUASAR sequence allows the extraction of AIF’s on a voxel-by-voxel basis from where the actual bolus length and dispersion can be extracted. The characteristic of the AIFs were assumed to approximate the Gaussian dissipation function proposed by Hrabe et al [6]. It is basically a convolution of the ideal AIF by a Gaussian distribution, applying a higher weighting of the longer traveling tailing edge. Because dispersion to some extent can mask the actual bolus length and visa versa, the actual bolus length was fitted in “parallel” within multiple AIFs from each dataset. This resulted in a global bolus duration and a dispersion parameter for each individual AIF. Only AIFs from voxels with a reasonable SNR were included. The accuracy of the method was tested using Monte-Carlo simulations where the actual AIF fit to real AIFs were compared to the gamma function which is also widely used for describing dispersed boluses. The effect of dispersion and unexplained bolus shortening is simulated for a standard 3-parameter (2 when using QUIPSS II) fit to multi time-point data as well as single TI acquisition at typical sample times of 1.5 and 1.8s. For the single TI distinction, a distinction has been made between the situation where tissue T1, arrival time etc is unknown (q=1 in [2]) and the situation where these parameters are known (q=true). General simulation parameters (results are average errors within these ranges): Blood T1=1.65s, tissue T1=1.2s, A=0.9, CBF=20-60ml/100g/min, transit time=0.4-1.0s, bolus duration=0.5-0.7s (Fig. 1b only), dispersion std.=0.0-0.2s (Fig. 1d only).

RESULTS and DISCUSSION: Fig. 1a shows the average dispersion estimated from 284 subjects (960 scans). As expected the dispersion increases in distal parts of the perfusion territories and interestingly, there is more dispersion in the posterior territory, probably due to the smaller feeding arteries (as compared to both ICAs) and longer tortuosity will result in dispersion differences, not only in between subjects, but also across the brain [1]. Generally, the bolus length is often expected to be well defined using QUIPSS II type of approaches [2], where the end of the bolus is cut off at a predefined time. However, from ultra sound studies it is known that large variability in blood velocities exist in brain arteries (65±19cm/s in distal ICA) [3] and here and how wide the label slab has been defined, the blood may have left the label region at typical cut-off times of 0.6-0.8s.

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