Introduction: Measurements of cerebral blood flow (CBF) and cerebrovascular reactivity (CVR) provide useful information about cerebrovascular condition and regional metabolism. Pseudo-continuous arterial spin labeling (pCASL) is a non-invasive MRI technique to quantitatively measure the CBF, whereas additional hypercapnic pCASL measurements are showing great promise to quantitatively assess the CVR. $^{15}$O H$_2$O positron emission tomography (PET) is currently regarded as the most accurate and precise method to measure CBF, though it is a highly invasive method as well. The main aim of the present study was to assess the accuracy of quantitative pCASL CBF and CVR measurements by performing a head-to-head comparison with $^{15}$O H$_2$O PET, based on quantitative CBF values under baseline (B) and hypercapnic (H) conditions. A second aim was to compare the precision of both $^{15}$O H$_2$O PET and pCASL by means of the intra- and inter-session reproducibility.

Materials & Methods: Sixteen healthy volunteers (9 male, 7 female, age range 20-24 years) were included in this study. MRI examinations were performed on a Philips 3T Intera system, equipped with an 8-channel receive head-coil. PET examinations were performed on a Philips Gemini TF-64 PET/CT system. For each modality, the volunteer underwent five (3 baseline and 2 hypercapnic) CBF measurements distributed over two sessions as depicted in figure 1. During baseline, normal air was administered through a mask set-up, while for the hypercapnic measurements the air delivery switched to a 5% CO$_2$ and 95% air gas mixture. A nasal capnograph placed within the mask measured the end-tidal CO$_2$ (eCO$_2$) for the CVR calculation. pCASL imaging parameters were: resolution: 3x3x7 mm$^3$, 17 slices, labeling duration: 1650 ms, delay: 1525 ms, GE-SSh-EPI read-out, BSup: 1680/2830 ms, NSA: 54, TR/TE: 3850/14 ms, T acq: 7 min. PET imaging consisted of an injection of 800 MBq $^{15}$O labeled water, followed by acquisition of 25 frames with gradually increasing duration for 10 minutes. After data acquisition, all CBF images were post-processed with SPM8. The accuracy was assessed by means of the equality in CVR and inter-modal agreement. Reproducibility was assessed by means of the reproducibility index (RI), which is defined as 1.96 times the standard deviation of the difference between successive scans, divided by the mean.

Results: Figure 2 shows an example of all 10 acquired CBF scans in a single volunteer. Table 1 shows the average grey matter (GM) CBF values, CVR, and reproducibility for each modality. Since 5 volunteers did not complete the full $^{15}$O H$_2$O PET acquisition scheme, the number of included volunteers is noted for each parameter. Solely for the combined conditions, a significant CBF difference of 3.6 ml/min/100g was observed between modalities, with no significant difference in reproducibility between PET and pCASL. Figure 3.A illustrates the overall quantitative CBF agreement between both modalities in a scatter plot with accompanying regression and correlations, the corresponding inter-modality Bland-Altman and voxel-wise scatter plot of the GM CBF with corresponding correlations. Additional to the voxel-wise GM correlations, whole brain voxel-wise correlations were: r$_{p=0.63}$, r$_{p=0.61}$ and r$_{p=0.64}$. The intra-session and inter-session reproducibility’s for both modalities are illustrated in figure 3.B.

Discussion and Conclusion: Quantitative analysis of the CBF and CVR showed a one-on-one agreement between $^{15}$O H$_2$O PET and pCASL, though a small overestimation of pCASL CBF was observed. The correlation between modalities was the total GM increased due to the hypercapnia from 0.30 to 0.47, which is in line with previous research (no correlation to r= 0.30-0.55)\(^2\).\(^\text{2,3}\). Voxel-wise correlations were also in line with previous research\(^2\) (r$^2$= 0.39 for only the GM of the baseline, group averaged data and r$^2$: 0.64 when also the WM was included). The RI of both modalities was not significantly different, illustrating that the reproducibility of pCASL is similar to $^{15}$O H$_2$O PET. To conclude, this research shows that pCASL is accurate with a precision comparable to $^{15}$O H$_2$O PET in GM regions.