# Validation of dual-injection dynamic susceptibility contrast perfusion weighted imaging against pseudo-continuous arterial spin labeling: a pilot study

Natalie M Wiseman[1], Meng Li[2], Mahmoud Zeydabadinezhad[3], Jessy Mouannes-Srour[3], Yongquan Ye[2], E. Mark Haacke[2,3], and Zhifeng Kou[2,3]

*[1]Department of Psychiatry and Behavioral Neurosciences, Wayne State University School of Medicine, Detroit, MI, United States, [2]Department of Radiology, Wayne State University School of Medicine, Detroit, MI, United States, [3]Department of Biomedical Engineering, Wayne State University, Detroit, MI, United States*

**Introduction:** Dynamic susceptibility contrast (DSC) perfusion weighted imaging (PWI) has long suffered from criticisms of unreliable determination of arterial input function (AIF), a necessary component for the deconvolution required in processing of the data. Some specific criticisms include blooming, clipping, and saturation effects in large vessels, which, at full doses of contrast, skew the relationship between concentration and decrease in intensity.

To combat this, we have used a dual-injection method, in which 1/6 of the contrast dose is used to determine the AIF and the remaining 5/6 is used to visualize the perfusion in brain tissue. We compared these cerebral blood flow (CBF) measurements to those obtained with pseudo-continuous arterial spin labeling (pCASL), an MR method for measuring CBF with good reliability that has been validated against the gold standard of positron emission tomography (PET)[1]. If it can match the reliability of the pCASL, the high resolution makes it preferable[2].

**Methods:** Two subjects underwent imaging with pCASL and DSC-PWI, and other conventional imaging sequences not discussed here. pCASL was performed as by Chen et al. [3] with isotropic resolution of 3.5 mm, TE of 22.76 ms, TR of 3500 ms, flip angle (FA) of 180°, and bandwidth (BW) of 2003 Hz/pixel. DSC-PWI was performed twice (with 1/6 of the dose, then with 5/6) with in-plane resolution of 1.33x1.33 $mm^2$, slice thickness of 4 mm and a 2 mm between slices, TE of 45 ms, TR of 1740 ms, FA of 65°, and BW of 1085 Hz/pixel. Two other subjects were scanned but issues with data quality did not allow using them for analysis.

The low-dose PWI scan was used to generate an AIF, which was scaled up according to the work by Mouannes-Srour, et al. (unpublished). This was applied to the high dose data, which resulted in the generation of CBF and cerebral blood volume (CBV) maps. The CBV map was used, along with an estimate of the percentage of tissue that is blood, to calculate a correction factor which was applied to the CBF map to account for the contrast present in the tissue during the scan. Additionally, for comparison, another CBF map was generated using only the high dose scan. The pCASL data was analyzed as proposed by Chen et al.[3] The mean CBF map was coregistered to the DSC-PWI scan with FSL, using a linear affine 12-parameter model. Both large and small regions of interest (ROIs) were drawn on the first time point of the PWI images, each consisting of a single tissue type, and transferred to the CBF maps. A correlation coefficient was determined between the pCASL and both AIF-predicted and not-predicted DSC-PWI CBF values.

**Results:** The correlation coefficients of 0.85 and 0.63 show good correlation in large ROIs between the AIF-predicted DSC-PWI and pCASL CBF values, and slightly poorer correlation in the small ROIs, respectively (Figure 2). PWI analysis performed with only the high dose data and no AIF prediction showed a worse $R^2$ of 0.76 in the large ROIs (not pictured here) and a much higher slope (2.71 as opposed to 1.40). The correlation was higher in one subject than the other, with $R^2$ of 0.93 and 0.72 in large ROIs.

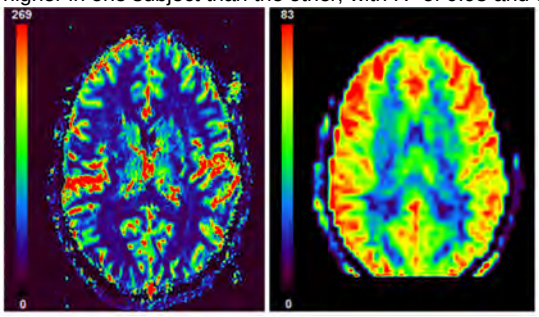


Figure 1. DSC-PWI CBF (left) and pCASL CBF (right) maps. The much higher resolution of the DSC-PWI map allows for distinction between cortical parenchyma and vessels, which, on the pCASL map, blend together.

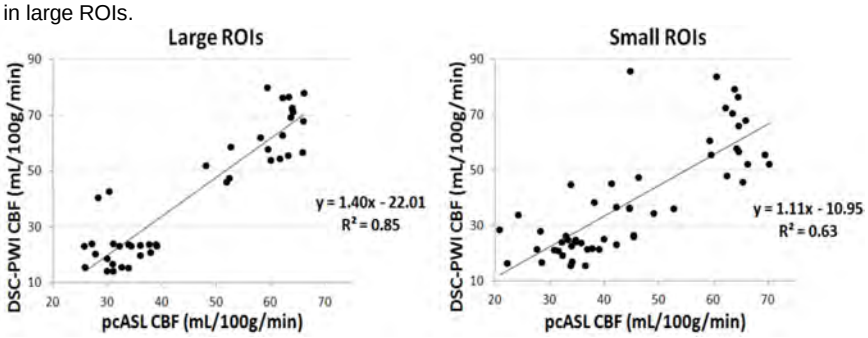


Figure 2. Comparison of DSC-PWI and pCASL in large (left) and small (right) ROIs. The correlations are better in the large ROIs, likely due to the greater impact of ROI placement in the small ROIs. Note the greater horizontal spread in the low CBF ROIs (white matter) and greater vertical spread in the higher CBF ROIs (gray matter).

**Discussion and conclusions:** The improvement of both $R^2$ and slope between DSC-PWI and pCASL when a low dose is used to determine the AIF supports our plan to use this method in the future for traumatic brain injury studies. While we did not validate our method against PET CBF determination, pCASL's validation against PET suggests that our measured values are accurate. The loss of correlation in smaller ROIs is likely due to the difference in resolution between the pCASL and DSC-PWI scans; the vessels and surrounding tissue of the cortex are quite distinguishable in the DSC-PWI scans, and the standard deviation is much higher than in the pCASL scans, which have a lower native resolution and nearly homogenous CBF values in the cortex. In the larger ROIs, the DSC-PWI values have less dependence on position and are more consistent with the pCASL data. The higher correlation in the second subject scanned is likely due to a change in the phase encoding direction, from right to left to anterior to posterior, which resulted in less distortion and therefore better registration with the DSC-PWI CBF map.

Additionally, the high resolution of the PWI scan will allow us to threshold out the vessels in the cortex (which have a much higher CBF than the surrounding tissue, skewing the measurement), which we would not be able to do with the lower-resolution pCASL. In summary, the dual-injection DSC-PWI method provides a reliable, high resolution measurement of CBF.

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**References:**

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