BOLUS PERFUSION-WEIGHTED IMAGING MEASUREMENT OF QUANTITATIVE CEREBRAL BLOOD FLOW CAN BE IMPROVED USING AN ARTERIAL SPIN LABEL DERIVED SCALING FACTOR: A COMPARATIVE XENON CT STUDY

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Introduction: Bolus dynamic susceptibility contrast (DSC) perfusion-weighted imaging (PWI) and arterial spin labeling (ASL) are two methods of measuring cerebral blood flow (CBF) using MRI. Each has different strengths and weaknesses. ASL CBF levels are reliable in high flow regions, but suffer from errors and low SNR in regions with long arterial arrival times. PWI, particularly when using delay-invariant deconvolution, is in theory unaffected by long arrival times. However, absolute quantitation is challenging, due to uncertainties in AIF & VOF partial volume and the nonlinear relationship between transverse relaxivity and contrast concentration. This study describes a method that uses ASL CBF measurements in regions with short transit delays (as measured by Tmax) to scale PWI CBF measurements. Stable xenon CT was used as a gold standard for CBF.

Methods: 16 patients with cerebrovascular disease (11M, 5F, mean age 56 yrs, range 29-74 yrs) had ASL and bolus PWI studies at 1.5 T and stable xeCT studies within 48 hrs. ASL CBF maps (6 min) were acquired using pseudocontinuous labeling (label time/post label delay 1.5/1.5 s) and background-suppressed 3D fast spin-echo readout with a resolution of 3 x 3 x 4 mm [1]. Bolus PWI (2 min) was performed using a 3-echo, 3-shot GRAPPA GRE PWI method (R=3, TR/TE = 1225/(17,30,52) ms, 0.1 mmol Gd) [2]. Hemodynamic maps (CBF, CBV, MTT, and Tmax) were created using automatic AIF detection and circular SVD [3]. 4 10 mm slices were acquired with XeCT starting at the level of the basal ganglia. CBF maps were produced using the Kety-Schmidt model.

The 3 image sets were coregistered using SPM5, and 1 cc cubic ROIs were compared (about 500 ROIs/patient). PWI correction consisted of scaling of all of the bolus PWI voxels by the ratio of the mean ASL CBF level and PWI CBF level in voxels with Tmax < 4 s (typically over 150 voxels). Between patients regression was also performed for mean global CBF.

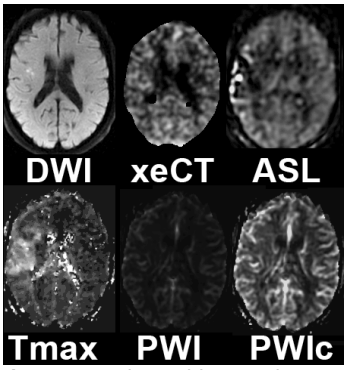

Fig 1: Co-registered images in a patient with ischemic stroke. Note that the use of the ASL scaling factor improves the bias of PWI CBF maps. There is better CBF correlation for corrected PWI in the low flow (long Tmax) region in the right frontal lobe than the ASL, which shows prominent arterial transit artifact.

Method	Mean CBF	CBF/xeCT (COV)	R
xeCT	36±9	1	n/a
ASL	31±6	0.90±0.24 (26%)	0.40±0.14
PWI	16±7	0.47±0.23 (50%)	0.40±0.28
PWI corrected	32±6	0.91±0.23 (25%)	0.40±0.11

Table 1: CBF values in ml/100 g/min. All values mean±SD

Results: Table 1 shows the quantitative results. ASL CBF maps had less bias and better precision compared with uncorrected bolus PWI. Applying the ASL correction factor resulted in a 2.3±1.2 fold increase in measured PWI CBF. The correction improved the bias and precision to a level equal with ASL. However, corrected PWI performed better than ASL in regions with long Tmax (Fig 2), with the correlation coefficient for all regions (n=704) increasing from R=0.35 to R=0.56. There was no relationship between the ASL scaling factor and the AIF partial volume correction factor (measured as the AIF-VOF area-under-the-curve ratio).

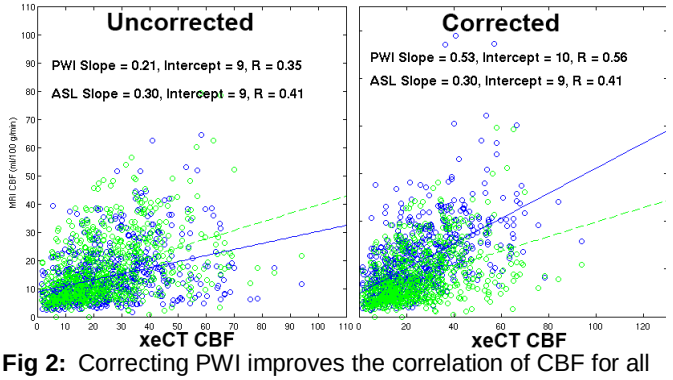

Fig 2: Correcting PWI improves the correlation of CBF for all patients, using xeCT as a gold standard (n=704 regions). ASL=green, PWI=blue.

Discussion: This study describes an approach to scaling bolus PWI CBF maps using information from a concurrent, coregistered ASL study. It relies on the idea that ASL more effectively measures absolute CBF for medium and high flow states. This correction factor is then used to scale the bolus PWI CBF maps, which should have improved performance relative to ASL in regions with long arterial arrival times. Presumably, this approach helps compensate for variability in the orientation and partial volume of the AIF and nonlinear contrast relaxivity issues in PWI [4]. Although not performed in the current study, the scaling factor could also be used to improve quantitative bolus PWI CBV measurements. In this respect, it is similar in principle to the "bookend" technique [5], which uses pre and post-contrast maps to calculate a CBV scaling factor (which is then also applied to the CBF maps). Also, this method is ideal for creating a scaling factor for spin-echo PWI CBF maps, in which determination of the AIF is fundamentally problematic.

Practically, a single global scaling factor will never improve correlation within an individual patient. Also, the upper limit of the improvement in between-patients correlation is set by the accuracy of ASL. However, specifically in regions with long Tmax, we found improved CBF correlation for corrected bolus PWI compared to either uncorrected PWI or ASL CBF. While we used a 6 min high resolution ASL sequence as this is part of our standard imaging, in principle, much lower resolution ASL CBF maps with shorter acquisition times could be obtained, since the scaling factor is determined from a relatively large volume of tissue. We conclude that the combined ASL-PWI method is superior to either method alone for measuring quantitative CBF with MRI.

References: 1. Dai et al., MRM 2008 ; 2. Newbould et al., MRM 2007 ; 3. Wu et al., *MRM* 2003 ; 4. Kiselev, MRM 2001 ; 5. Sakaie et al., JMRI 2005.