

Precision and Accuracy of Arterial Spin Labeling Perfusion MRI in the Pediatric Population

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Introduction

Arterial Spin Labeling (ASL) provides a noninvasive means for measuring quantitative cerebral blood flow (CBF) without the use of exogenous contrast agents, and is particularly appealing for pediatric populations (1). In neurodevelopmental studies, quantitative CBF can serve as an important marker of cognitive development in normal children as well as aberrant changes in brain function in childhood brain disorders. The purpose of the study was to evaluate the precision (longitudinal reproducibility) and accuracy (against phase-contrast MRI) of absolute CBF measurements using two ASL techniques, pulsed ASL (PASL) and pseudo-continuous ASL (pCASL) in a typical developing pediatric cohort.

Methods

All scans were performed on a Siemens 3T Verio Scanner using 32channel head coil. Eighteen normal pediatric subjects (Age 7-17 years, 10 males, 9 Caucasian, 4 African American, 3 Asian, 2 mixed) were recruited after informed consents were obtained from a parent or legal guardian. Each subject was scanned twice within 2-4 weeks. The PASL sequence was a Siemens product version of the Q2TIPS technique [2]. Imaging parameters were: TR=3s, TE=11ms, matrix=64x64, gradient-echo EPI with rate-2 GRAPPA. The pCASL sequence was the balanced gradient version described in [3]. Imaging parameters were: TR=4s, TE=22ms, matrix=96x96, spin-echo EPI with rate-2 GRAPPA. The labeling slab (10cm thick) was 4cm below the lowest imaging slices in PASL and the labeling plane was 9cm below the center of imaging slices in pCASL. Common parameters for PASL and pCASL included FOV=20cm, 16 slices with 6mm thickness and 1.2mm gap and post-labeling delay time of 1.2s. Total scan time with 80 acquisitions was 4min for PASL and 5.5min for pCASL. A segmented multiphase IR TrueFISP sequence was used for blood T1 measurements at the level of superior sagittal sinus [4]. Time resolved flow velocities in the internal carotid and vertebral arteries were measured using a pulse-gated Phase-Contrast (PC) sequence at the identical position of the labeling plane of pCASL. Imaging parameters were: FOV = 20 cm, matrix size = 256 x 256, flip angle=15°, TR=25ms, TE=5ms, 5mm slice thickness and velocity encoding = 100cm/s. A 3D MPRAGE scan was used for high resolution T1-weighted anatomic images for the estimation of brain volume. Quantitative CBF was calculated using standard one-compartment perfusion model with and without incorporating in vivo blood T1, respectively. For PC MRI, a mask created from the magnitude images was superimposed on the phase difference images to obtain the average blood velocity (mL/min) in the main feeding vessels to the brain. The average blood velocity was divided by the brain volume estimated from MPRAGE images using a semi-automated segmentation algorithm implemented in ITKSnap [7] to obtain CBF in standard units (mL/100g/min). The reproducibility of ASL global CBF measurements was analyzed by computing the intra-class correlation coefficient (ICC) and within-subject coefficient of variation (wsCV) between 2 repeated scans. Further, the accuracy was determined by

computing the ICC between global CBF measurements obtained using PC MRI with PASL and pCASL respectively, using PC MRI as the gold standard.

Results and Conclusions

The pCASL global CBF measurements showed higher test-retest reliability between repeated scans 2-4 weeks apart, compared to PASL measurements (ICC: 0.62 vs. 0.31) (Figure 1a,1b, Table 1). The computed wsCV for pCASL and PASL CBF measurements was 7.69% and 14.36%, respectively (Table 1). As expected, PC MRI demonstrated a high degree of reliability (ICC: 0.98). Using global CBF calculated using PC-MRI as the gold standard, pCASL showed a higher degree of accuracy than PASL measurements (ICC: 0.77 vs. 0) (Figure 1c,1d). The fitted slope between pCASL and PC-MRI was 1.08, and the calibrated mean labeling efficiency of pCASL was 88% in the pediatric cohort tested. However, upon incorporating in vivo blood T1 values into CBF calculation of pCASL measurements, while the reproducibility of the measurements increased between the test-retest conditions (ICC: 0.74), the accuracy as compared to PC-MRI decreased (ICC: 0.59). The wsCV after T1 correction for CBF measurements with pCASL was 7.49%. The PASL measurements showed no improvement in reproducibility or accuracy after T1 correction. Developmental changes in global CBF measured by PC MRI and pCASL showed a decreasing trend with age (p<0.001). In conclusion, our results demonstrate excellent precision and accuracy of quantitative CBF measured by pCASL in healthy children 7-17 years. The decrease in accuracy upon implementing in vivo blood T1 correction may be attributed to other uncalibrated factors in the pediatric population (e.g. increased flow velocity may lead to reduced labeling efficiency). The poor accuracy of PASL may be related to the variable tagging bolus in children with different head sizes [6] whereas the position of the pCASL labeling plane is relatively uniform across age groups.

References

[1]Wang & Licht, Neuroimaging Clin N Am. 2006 Feb;16(1):149 [2] Luh et al MRM 1999 41:1246 [3] Wu et al MRM 2007, 58:1020 [4] Wu&Wang ISMRM 09 [5] Yushkevich et al Neuroimage 2006,31:1116-28 [6] Wang et al. MRI 2006,24: 249-54.

Acknowledgement

This work was supported by grant MH080892

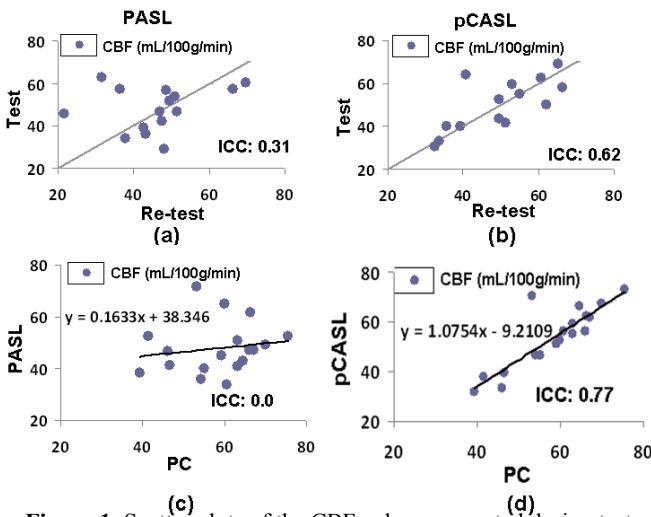


Figure 1: Scatter plots of the CBF values computed during test and re-test conditions using (a) PASL (b) pCASL and comparison of PC-MRI computed CBF measurements with (c) PASL and (d) pCASL measurements

	ICC	wsCV (%)
PASL	0.31	14.36
pCASL	0.62	7.69
PASL-T1	0.36	16.72
pCASL-T1	0.74	7.49

Table 1: Intra-class correlation coefficient (ICC) and within subject coefficient of variation (CV) for the uncorrected and T1-corrected test-retest conditions.