A Comparative Study of Absolute Functional CBF Measurements in Normal Human Brain using PASL MRI and [O-15]water PET

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Introduction In a previous PASL/PET study [1] absolute resting state rCBF values measured using PASL in a single slice were compared with those measured in the same group of human subjects using the [^{15}O]water IV bolus PET method. This study is to validate multiple-slice CBF measurements by PASL against those measured by PET and to test reproducibility of PASL CBF measurements. The resting and activated state CBF was measured by PASL and task-induced changes in CBF were estimated in functionally and anatomically defined cortical regions. These values were compared to those measured in PET experiments using the same tasks in the same the subject group.

Methods and Materials Thirteen consenting healthy subjects (males, 27±6 years) were recruited. For each subject, 3 visits were scheduled on different days, twice for MRI, once for PET, maximally 4 weeks apart. MRI was performed on a 3T whole-body scanner Trio (Siemens Medical Systems, Erlangen, Germany) with a CP head coil. EPISTAR QUIPSS ASL MRI [2] was used to measure CBF in the presence of motor/visual stimuli. The acquisition parameters were: FOV = 240x264 mm^2; matrix = 60x64; bandwidth = 2442 Hz/pixel; slice thickness = 6 mm (gap 3 mm). Ten AC-PC aligned slices were acquired from inferior to superior in an ascending order; between the imaging and labeling slabs there was a 20-mm gap. For the motor task, the whole imaging slab was positioned on the upper part of the brain, with the lowest slice passing through AC-PC; for visual stimulation, the imaging slab positioned on the lower part of the brain, with the 7th slice from the bottom going through AC-PC. Acquisition of each slice took approximately 60 ms. TI = 1400 ms; TR = 2000 ms; TE = 21 ms; T1a = 1490 ms; λ = 0.9 ml/g; α_π = 0.95, and TI_1 = 700 ms. The T_{1app} map was measured by an ultrafast Look-Locker echo-planar imaging sequence [3]. Unilateral finger tapping was visually guided at ~3 Hz; visual stimulation was an 8-Hz BW flicking checkerboard. They were presented in one-minute blocks of stimulation alternating with one-minute periods of rest. Two PASL runs of 160 images per slice were acquired for either visual or motor. PET imaging was performed using the High Resolution Research Tomograph (HRRT) which acquires 207 slices (1.2 mm slice separation) with reconstructed image resolution of ~3 mm. A 6-min transmission scan was acquired for attenuation correction. Twelve bolus injections (20-s duration) of 20 mCi of [^{15}O]water each were administered through an intravenous line at intervals of 10 mins using an infusion pump. List mode data were acquired on the HRRT for each scan. Acquisition of HRRT list mode data began shortly before each injection. Simultaneously, the arterial input function was measured with an automated blood counting system (PBS-101, Veenstra Instruments) using continuous withdrawal system with a peristaltic pump (4 ml/min). The radioactivity in whole blood was measured with a calibrated radioactivity monitor. Subjects were asked to perform visual and motor tasks during the 12 [^{15}O]water scans. The task acquisition (performed in random order) consists of: 4 baseline, 4 visual, 4 finger tapping in the hand opposite to the intra-arterial line placement. The presentation of tasks had the pattern of "off-on-off-on-off", each for 60 second (total of 5 min) with the first "on" period coinciding with tracer injection.

Results and discussion A standard whole brain template (MNI-1mm) was used for subject spatial normalization of the MRI and PET individual data. Visual and left motor ROIs were functionally defined based on task-induced changes in CBF measured by PASL (Fig 1). Other 12 gray ROIs were (anatomically) defined based on the AAL atlas [4]. The global baseline CBF was calculated from the baseline CBF scans during motor (upper) and visual (lower) stimulation. No significant changes in resting state global CBF were found between measurements of PET, MR session1 and MR session 2 (Table 1). The baseline CBF and task-induced absolute and relative CBF changes were also estimated within all the ROIs for each subject and then pooled across subjects. Pair-wise comparisons of values (PET/MR, MR session 1/session2) were carried out for each ROI and subject. The resting state CBF in the anatomically defined ROIs measured by PASL was significantly different from that by PET (Table 2). Over all ROIs inspected, the task-induced changes in CBF detected by PASL were significantly greater than those by PET (Table 2). Both the resting state CBF and the task-induced changes in CBF measured by PASL in 2 MR sessions showed good reproducibility in the PASL CBF measurements (Table 3). The sample size using PASL for detection of the mean task-induced change in rCBF with a 95% confidence and an 80% statistical power was calculated (Table 3). In summary, using the PASL protocol described, the global resting CBF measured by PET and MR agrees; however discrepancies in local CBF were found. Task-induced CBF changes measured by PASL are larger than those by PET and this was observed over all ROIs inspected, regardless of how they were defined; this difference may be attributed to differences in the hemodynamic response times of the two modalities. PASL showed good reproducibility in CBF measurements.

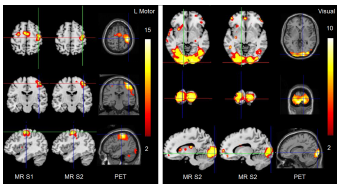

Fig 1 Task-induced changes in CBF measured by PASL and PET for motor (left) and visual (right) ROIs.

References: [1] Ye et. al. 2000. MRM 44(3):450-6; [2] Luh WM et. al. 1999. MRM41(6);1246-54; [3] Freeman AJ et. al. 1998. MRI 16(7):765-72; [4] Tzourio-Mazoyer N et. al. 2002. Neuroimage 15(1):273-89.

PET	MR	Δ(MR-PET)	MR S_1	MR S_2	Δ(S_2-S_1)
50.3±5.85	49.26±7.25	-1.04±3.6	48.91±7.59	49.62±5.51	-0.72±6.24

CBF unit is ml/100g/min; * p<0.05; ** p<0.01.

Table 1 Comparison of subject-pooled resting state global CBF measured with PET and PASL (2 sessions).

Regional CBF[1]	PET rest	MR rest	Δrest	PET diff	MR diff	Δdiff
absolute/functionally defined ROIs	47.91±9.82	49.21±13.55	-1.30±11.02	8.21±6	12.21±5.99	-4±4.68**
relative /functionally defined ROIs	0.971±0.193	0.988±0.234	-0.018±0.21	0.167±0.133	0.245±0.113	-0.078±0.087**
absolute/anatomically defined ROIs	47.55±15.09	49.87±14.34	-2.32±14.76*	2.5±3.17	4.21±4	-1.7±3.62**
relative /anatomically defined ROIs	0.947±0.259	1.019±0.344	-0.073±0.28**	0.051±0.064	0.087±0.084	-0.037±0.075**

[1] ml/100g/min; * p<0.05; ** p<0.01.

Table 2 CBF measured by PET and PASL.

Regional CBF[1]	S_1 rest	S_2 rest	Δrest	S_1 diff	S_2 diff	Δdiff	N
absolute/functionally defined ROIs	49.83±14.75	49.67±14.28	-0.16±10.99	13.43±7.36	11.43±7.38	-2±8.81	8
relative /functionally defined ROIs	0.983±0.227	1.015±0.269	0.0315±0.1664	0.268±0.149	0.23±0.145	-0.038±0.19	5
absolute/anatomically defined ROIs	49.8±14.52	49.94±15.32	0.15±8.29	4.26±4.65	4.15±5.65	-0.11±6.56	35
relative /anatomically defined ROIs	1.017±0.345	1.021±0.362	0.004±0.165	0.088±0.0977	0.0867±0.116	-0.0013±0.133	33

[1] unit for absolute CBF is ml/100g/min; * p<0.05; ** p<0.01.

Table 3 CBF measured in 2 MR sessions. N is the sample size using PASL for detection of the mean task-induced change in rCBF with a 95% confidence and an 80% statistical power.