Regional Distribution, Laterality, and Reliability of Volumetric Cerebral Perfusion Imaging in Healthy Adults

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Background. Selective cognitive, sensory, and motor functions depend on the health of the local blood perfusion in the brain. Delineation of patterns of regional cerebral blood flow (rCBF) can aid in identifying patterns of sparing and impairment of selective functions associated with disorders of the brain. Here, we sought to characterize the regional distribution and laterality of CBF and to test the reliability of volumetric arterial spin labeling (ASL) measurements of CBF in cortical, subcortical, and cerebellar regions of interest (ROIs).

Methods. We acquired a whole brain pseudo-continuous ASL 3D perfusion sequence[1] (TR=1381ms, TE=5.2ms, thick=5 mm, skip=0, xy matrix=518x8; flip angle=155°, locations=36) and accompanying structural data (SPGR 1.3 mm thick and FSE 2.5 mm thick) in 10 healthy control men and women. Subjects were scanned twice, separated by 3 to 7 days. The FSE and SPGR were used for skull stripping, image registration and ROI identification. Skull-stripped images were generated by running FSL BET on the SPGR, early-echo, and late-echo FSE images separately and combining the resulting brain masks by voting after reformatting the two FSE masks into SPGR space. Bias-corrected FSE images were aligned with bias-corrected SPGR images via nonrigid registration.[2] The SPGR images were then segmented into three tissue classes (CSF, gray and white matter) using FSL FAST.

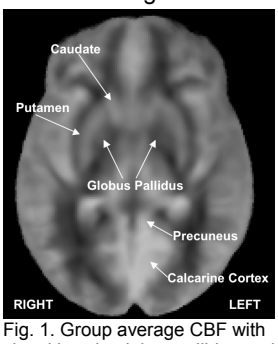

Fig. 1. Group average CBF with signal loss in globus pallidus and L>R CBF in posterior cortex.

For each subject and session, CBF data were aligned with the gray-matter probability map. The rationale being that CBF signal is expected predominantly in gray matter. 33 ROIs were identified by clustering adjacent lobar parcellations from the SRI24 atlas.[2] Data were analyzed as raw CBF in ml/100cc_gray_matter/min for each ROI. To account for subject differences in global CBF and express the data in effect size, each individual's data were normalized by dividing the CBF value of each voxel minus the mean of the whole brain CBF by the standard deviation of the whole brain CBF. Via concatenation, all CBF images were reformatted into SRI24 coordinate space for group-average display (Fig. 1).

Results

Regional Distribution. The average cortical CBF was 39.5, and CBF differed two-fold across the cortical ROIs, with the posterior cingulate cortex having the highest CBF. Subcortical structures had lower CBF than cortical or cerebellar regions, and the globus pallidus had the lowest CBF. The rank ordering of the ROIs was essentially the same from time 1 to time 2 (Fig. 2).

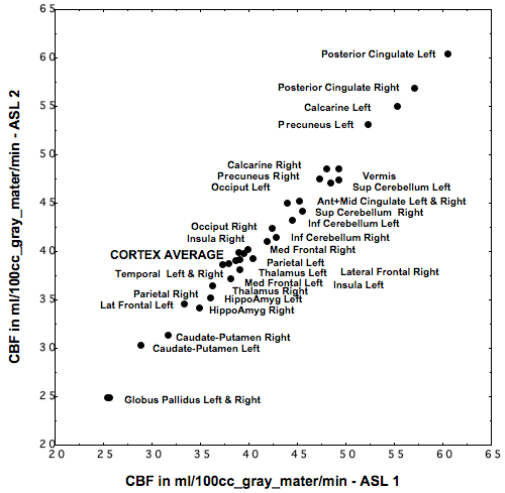

Fig. 2. ASL1 vs. ASL2 for 33 ROIs.

Lateral Asymmetry. Lateral asymmetry, tested with paired t-tests on global normalized data, revealed several significant laterality effects, with frontal regions having greater right than left and posterior regions having greater left than right perfusion (Fig. 3).

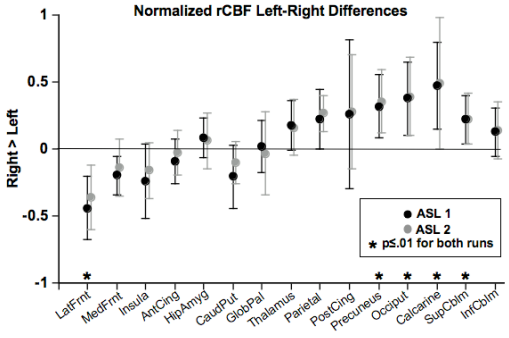

Fig. 3. Mean±SD for left-right asymmetry of rCBF.

Reliability. Test-retest reliability was estimated by correlating all normalized ROIs across all subjects for time 1 vs. time 2 (330 paired observations). The coefficient of determination was r^2=.92 and intraclass correlation r=.96 (Fig. 4).

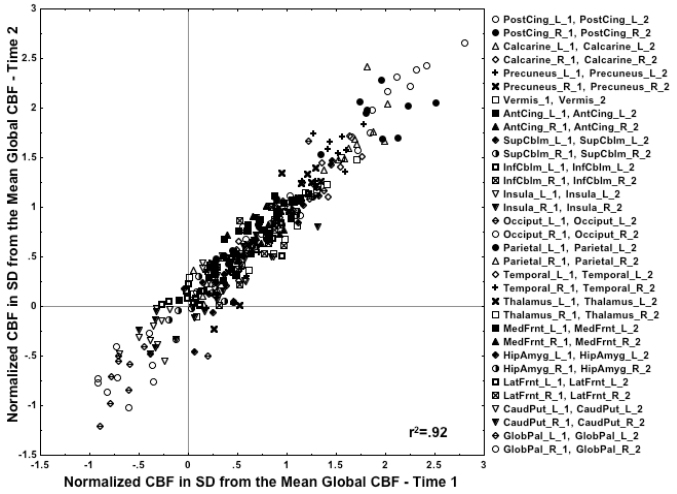

Fig. 4. ASL1 vs. ASL2 for 330 pairs (10 subjects by 33 ROIs).

Discussion and Conclusion. Regional CBF, normalized for global perfusion, was highly reliable when measured on separate days. There was considerable regional variability and several regions of significant lateral asymmetry. The posterior cingulate cortex had the highest perfusion and the globus pallidus the lowest. The low globus pallidus rCBF may be due to iron-induced signal attenuation as it is among the highest iron-laden structures in the brain.[3] The high rCBF in the posterior cingulate cortex in this task-free acquisition is consistent with its identification as a principal node of the "default mode network."[4]

Acknowledgment. NIH AA010723, AA005965, AA012388, AG017919

References

1. W. Dai, D. Garcia, C. de Bazelaire, D. C. Alsop, *MRM* **60**, 1488 (2008).
2. T. Rohlfing, N. M. Zahr, E. V. Sullivan, A. Pfefferbaum, *Human Brain Mapping* (2009).
3. A. Pfefferbaum, E. Adalsteinsson, T. Rohlfing, E. V. Sullivan, *Neurobiology of Aging* (2009).
4. M. Raichle *et al. Proceedings National Academy of Sciences* **98**, 676 (2001).