Long-term Reproducibility of PCASL with a Background Suppressed 3D Single-shot Readout Sequence

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Introduction

Most previous reproducibility studies of Arterial Spin Labeling (ASL) have assessed within-session or short-term reproducibility (at 1 week intervals) (1, 2, 3) and most of them have been performed in young volunteers. The purpose of this study was to assess long-term reproducibility at monthly intervals, in a group of older adults. This information can be useful for planning longitudinal studies that are usually carried out during periods of several months.

Materials and Methods

Studies were performed on a 3T Siemens Trio using a 12-channel head array. Eight healthy volunteers (3F, age=55.9±7.6 years) participated in the study after signing informed consent. Each subject was scanned 4 times at intervals of 1.5 months (i.e. scan 1=baseline; scan 2/3/4=1.5/3/4.5 months after the baseline scan). During each scanning session resting perfusion was measured using a pseudo-continuous ASL (PCASL) technique (4) and a 3D single-shot GRASE readout with background suppression (BS) (5) (TEeff=56ms, TR=3.5 sec, resolution=4x4x7 mm^3, FOV=250x188x112 mm^3, 16 nominal partitions with 13% oversampling, 5/8 partial Fourier in partition encoding, matrix size=64x49, BW=2790 Hz/pixel, BS TI1=1800 ms, TI2= 500 ms). The labeling time was 1.6 sec and post-labeling delay was 1.5 sec. 50 label/control pairs were acquired in a scan time of 6 min, followed by a short scan of 5 label/control pairs acquired without BS to obtain control images needed for cerebral blood flow (CBF) calculation. The images were processed using SPM and custom scripts in Matlab. Each subject's images were realigned and co-registered to the anatomical dataset, acquired using a T_1-MPRAGE sequence, before subtraction of label and control. 49 perfusion images were obtained, after discarding the first label/control pair. A CBF map was computed from the mean perfusion image using the one-compartment model (6). The anatomical images were segmented and a whole brain mask was generated by adding the gray and white matter tissue images. Whole brain mean CBF was computed by averaging CBF voxel values within the mask. The degree of BS was calculated as the ratio of the whole brain mean signal intensity in the background suppressed images to the signal intensity in the unsuppressed images. CBF change over time was evaluated using a one-way repeated-measures ANOVA with the factor scan number. Before assessing reproducibility, differences between whole brain CBF measurements were tested for normality using the Shapiro-Wilk W-test. Next, two reproducibility indices were calculated: the within-subject coefficient of variation (wsCV) and the intraclass correlation coefficient (ICC). For each subject, the CV was computed as the ratio of the standard deviation to the mean of repeated measurements, for each pair of measurements (i.e. between the baseline scan and each of the other 3 scan sessions) and for all the obtained measurements combined. The wsCV was then calculated as the squared root of the mean sum of squares of the individual values. The ICC was computed for all measurements combined, using a two-way model, single measure in SPSS. The effect of BS on reproducibility was explored by evaluating the correlation between the 8 subject values of the whole brain CBF CV and the degree of BS.

Results and Discussion

Figure 1 shows CBF maps acquired in the four scan sessions from a representative subject. Fig. 2 shows individual whole brain mean CBF values for scans 2, 3 and 4, plotted with respect to baseline values. The ANOVA results confirmed that there was no statistically significant difference between the whole brain mean CBF values acquired over the study period. The Shapiro-Wilk test indicated that the CBF data were normally distributed. Reproducibility results are shown in Table 1. The wsCV remained approximately constant for all scan intervals, ranging from 7.98 to 11.76 %. The ICC over the total study period was 0.663 with 95% CI (0.333-0.906). These values are in agreement with previous reproducibility studies carried out at weekly intervals using several ASL variants (3, 2) and they are higher than the reported long term reproducibility of PASL (7). The degree of BS was very stable between scans for all subjects except 2 (see Fig. 3), with the variability in the degree of BS (standard deviation of the 4 scan sessions) ranging from 0.02 to 2.27. There was no correlation between the degree of BS (mean or standard deviation) and the individual CVs of the whole brain CBF (r^2=0.0621 and r^2=0.0013, respectively) (Fig. 3). The long term variability in the CBF measurements is likely related to physiological factors rather than measurement error, although variability in the labeling efficiency, which has not been measured in this study, could play a role.

Table 1: Summary of reproducibility results.

	CBF (mean ± SD)	wsCV [%]
Scan 1 (baseline)	36.04 ± 7.29	
Scan 2 (1.5 months)	37.72 ± 4.55	11.76
Scan 3 (3 months)	39.61 ± 4.26	11.66
Scan 4 (4.5 months)	36.52 ± 6.74	7.98
All measurements	37.47 ± 5.75	10.11

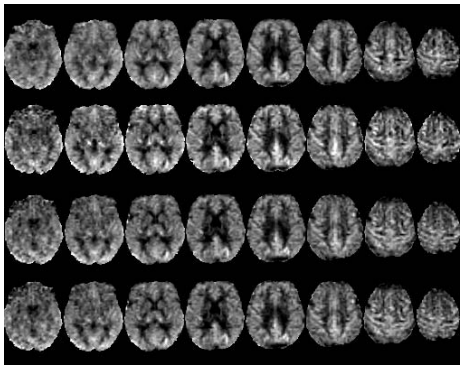

Fig. 1: CBF maps acquired in the four scan sessions from a representative subject.

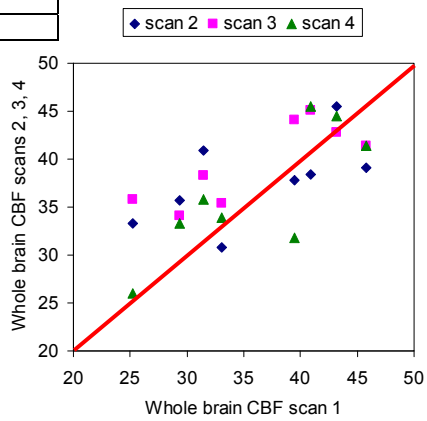

Fig. 2: Plot of individual whole brain CBF for scan sessions 2/3/4 (1.5, 3, 4.5 months, y-axis) with respect to scan 1 (baseline, x-axis). The identity line is shown in red.

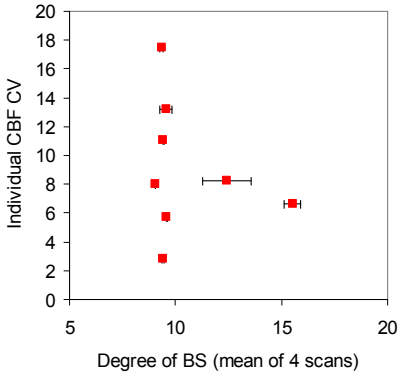

Fig. 3: Plot of individual coefficient of variation of whole brain CBF (y-axis) with respect to the mean degree of BS (x-axis). The horizontal bars represent the standard deviation of the degree of BS across scans.

Conclusions

Resting state perfusion measurements obtained with PCASL showed good reproducibility over a period of 4 months. PCASL has the potential to be used for quantifying perfusion in longitudinal studies.

Bibliography

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