AN AUTOMATED POST PROCESSING ANALYSIS TO INCREASE DETECTABILITY OF CEREBRAL BLOOD FLOW ARTERIAL SPIN LABELING IMAGES IN THE PRESENCE OF HEAD MOTION

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Purpose: Arterial spin labeling (ASL) is a non-invasive MRI technique for absolute cerebral blood flow (CBF) quantification. It is a cost-effective and relatively fast MR technique, which makes it beneficial for repetitive scans to monitor disease progression and therapy. With all the advantages that ASL offers, this technique, however, suffers from a low signal to noise ratio (SNR). [1,2] Furthermore, unexpected variations of control and tag images resulting from head motion, physiological noise and hardware instabilities can influence image quality and therefore impact the CBF information. [1,3] In this study, we propose to address the issue of head motion in ASL quantification, which in many cases will be the dominant source of error, by developing a pass/fail criterion for individual ASL differences images. This novel ASL analysis pipeline may help to improve the clinical viability of ASL perfusion imaging.

Methods: We examined ASL data from three cohorts in this study (total sample: 67): twenty teenagers diagnosed with bipolar disorder (BD), ten chronic stroke (CS) adults and thirty seven adults with moderate to severe cerebral small vessel disease (SVD). All three cohorts were suspected of having an underlying perfusion abnormality and hence the need to maximize image quality. To optimize CBF image, an automated analysis pipeline was used to classify control-tag pairs as pass/fail based on whether or not they contribute to a higher quality perfusion image. Control-tag difference (CBF difference) images were sorted in ascending order on the basis of their corresponding motion parameters obtained from pair alignments to a reference ASL volume. Sorted CBF difference images were then examined using an exclusion criterion to be identified as pass/fail. The criterion was to achieve the maximum proportion of non-zero voxels in the grey matter (GM) in perfusion image. A non-zero voxel is defined as having a signal intensity that is significantly greater ($p<0.05$) than zero on a 1-tailed t-test (a parametric test was deemed appropriate). Temporal SNR (SNR_t) was used to evaluate employing of optimization pipeline for CBF quantification. The change in SNR_t relative to the conventional CBF quantification (including all the CBF difference images) was calculated as ΔSNR_t.

Results: Figure 1A demonstrates the proportion of GM non-zero voxels as successive CBF difference images are included to contribute to the perfusion image for a patient from the SVD group. Figure 1B shows the constructed CBF image using optimization pipeline (CBF_{opt}) for this participant. Statistical analysis on ΔSNR_t values, obtained from 67 subjects, found that the optimization procedure significantly increased GM SNR_t ($p<0.001$). The GM ΔSNR_t was zero for 16 of the 67 participants (i.e. 5 BD, 3 CS and 8 SVD), indicating that optimization was not required and the conventional ASL analysis was sufficient. For the remaining 51 participants, the optimization improved GM SNR_t by 9% (mean quoted, range was: 0.5%-60%). Table 1 summarizes cohorts' demographics as well as parameters calculated for group comparison. One-way analysis of variance found a significant cohort effect on all parameters (age, GM SNR_t, GM CBF, proportion of GM non-zero voxels and motion) ($p<0.001$) except for GM ΔSNR_t ($p=0.129$). Moreover, results of regression analysis found that all parameters were significantly correlated with age ($p <0.05$, within the 67 patients).

Conclusion and discussion: A novel ASL analysis pipeline to optimize clinical perfusion images was proposed and validated in participants that spanned a large age range and brain conditions. Our technique significantly increased the SNR_t of perfusion images relative to the conventional ASL analysis. We also performed CBF quantification using a recently developed approach by Wang et al [4] for a number of our participants and observed equal or higher voxels detectability in perfusion images calculated from our optimization method relative to Wang's approach (data not shown). Our results also indicate that our approach increases SNR_t more dramatically among older adults, such that lower quality CBF images tend to benefit more from the optimization pipeline. Therefore, using the optimization method is likely critical for aging / clinical studies as a means to improve diagnostic value. Future work will establish whether this novel technique can be used as part of early diagnosis and treatment monitoring of neurodegenerative disorders and thereby ASL-based perfusion as a sensitive biomarker.

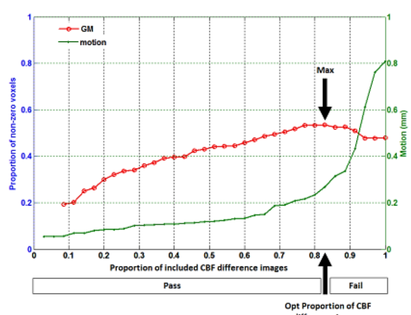

Figure 1A. The effect of incorporating a larger proportion of the CBF difference images for an 88 year old SVD man, sorted by head motion accrued during the individual ASL images. (left y-axis: proportion of GM non-zero voxels; right y-axis: motion estimates in mm).

Figure 1B. CBF_{opt} image for this patient in coronal, axial and sagittal views (left to right).

Table 1. Cohorts' demographics as well as between groups' comparison of evaluation parameters. Mean ± STD is demonstrated.

	BD (N=20) F/12	CS (N=10) F/4	SVD (N=37) F/17
Age (years)	16.7±1.4	58.5±15.5	73.8±8.4
GM ΔSNR_t (%)	3.4±4.8	6±7.4	8.8±11.7
GM $SNR_{t,opt}$	1.4±0.2	1±0.3	0.6±0.2
GM CBF_{opt} (mL/100 g /min)	82.1±16	61.2±25	50.8±15
proportion of GM non-zero voxels	0.9±0.03	0.8±0.07	0.7±0.2
Motion (mm)	3.2±1.1	4.9±2.6	7.1±3.6

References

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