Comparison of PWI, DWI, and clinical outcome for suspected stroke

Neil Chatterjee[1], Shyam Prabhakaran[2], Sameer Ansari[1], and Timiothy Carroll[1]
[1]*Radiology, Northwestern University, Chicago, IL, United States,* [2]*Neurology, Northwestern University, Chicago, IL, United States*

Purpose: MRI perfusion and diffusion imaging have become important tools in the evaluation of cerebrovascular disease. However, there is still much uncertainty and debate about the respective roles of perfusion weighted imaging (PWI) and diffusion weighted imaging (DWI). One of the reasons for this continued uncertainty is the difficulty of conducting large scale research studies using PWI and DWI images. Cerebral blood flow (CBF) images of often analyzed clinically by drawing and comparing regions of interest (ROIs), but because this process is time intensive and prone to bias, it is not well suited for large research studies. Previously, we introduced a method for automation of CBF image analysis by automatic construction of vascular territory ROIs [1]. Here, we apply this method to a cohort of 109 patients scanned with a suspicion of acute stroke or transient ischemic attack and investigate the correlation between PWI, DWI, and clinical outcome.

Methods: 109 patients suspected of having an acute stroke or transient ischemic attack were recruited as part of an ongoing IRB-approved prospective study (Northwestern University Brain Attack Registry, NUBAR). Patients received a perfusion scan performed clinically within 12 hours of symptom onset, and various clinical metrics were collected. This particular cohort consists of patients who received a perfusion scan and who had a modified Rankin Scale (mRS) recorded at 3 months after enrollment.

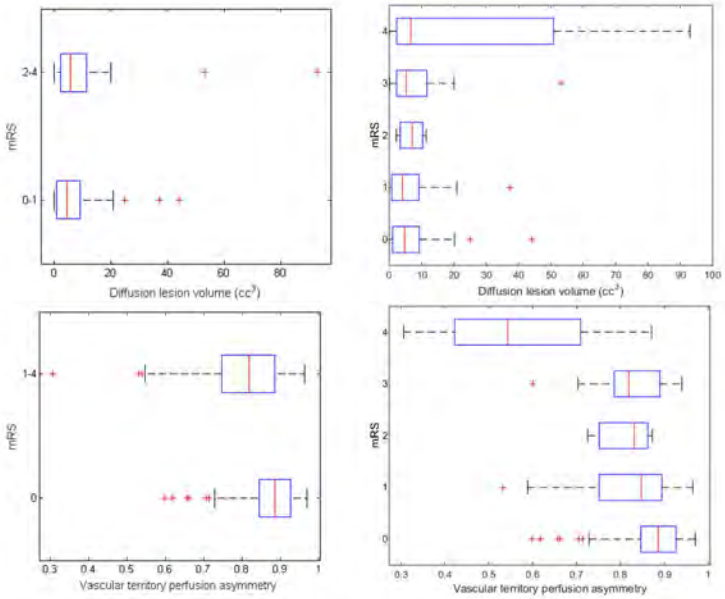

Figure 1: Perfusion asymmetry and ADC lesion volume binned by modified Rankin Scale taken 3 months after the initial event

CBF images were calculated from a perfusion image series (13-15 slices, 5mm thickness, TR/TE 1500/45, 128x128, 22cm FOV) offline using automatic AIF selection [2] and SVD deconvolution [3]. CBF images were then analyzed by automatic construction of vascular territory ROIs[1]. In brief, a vascular territory template consisting of superior and inferior middle cerebral artery (MCA), anterior cerebral artery (ACA), and posterior cerebral artery (PCA) territory ROIs is warped to fit each subject, and the ROIs are used to calculate perfusion asymmetries in each ROI between the left and right hemispheres. A theoretical normal asymmetry index is 1 with lower values indicating increasing asymmetry between the hemispheres. For each subject, the minimum asymmetry index (ie the territory with the greatest perfusion abnormality) was chosen for analysis.

Diffusion images were analyzed using automated diffusion coefficient (ADC) images. ADC images were first masked to exclude non-brain tissue. Lesion volume was then calculated automatically by summing the number of voxels in clusters of at least 10 that fell below a threshold of 550. All comparisons between groups were done using a two-tailed t-test.

	mRS 0 (N=58)	mRS 1 (N=33)	mRS 2 (N=3)	mRS 3 (N=11)	mRS 4 (N=4)
ADC volume	7.0±7.8	6.7±8.5 (p=.89)	6.9±4.6(p=.99)	10.5±15 (p=.24)	26.6±44(p<.01)
Perfusion asymmetry	.86±.09	.82±.11 (p=.01)	.81±.08(p=.32)	.81±.10 (p=.10)	.57±.23(p<1e-6)

Table 1: Comparison of perfusion asymmetry and ADC volume in each mRS group compared to a refernce group with mRS=0

Results: Box plots of perfusion asymmetry and ADC lesion volume binned by 3 month mRS are shown in Figure 1. There was no significant difference in ADC volumes for patients with a mRS of 0-1 vs mRS >1 (p=.36), but there was a significant difference in perfusion asymmetry (p<.01). Patients were also grouped by individual mRS score. ADC volume and asymmetry in each group with mRS >0 were compared to a reference group with an mRS of 0 (Table 1). When comparing ADC volumes between mRS groups, only the group with mRS of 4 had volumes significantly different than the reference group. When comparing perfusion asymmetry between mRS groups, asymmetry was significantly different from the reference group in groups with mRS of 1 and 2 and trended towards significant difference from the reference group in the mRS 3 group.

Discussion: Using fully automated processing methods, we investigated the correlation between perfusion deficit, diffusion deficit, and clinical outcome. When examining patients with an mRS of 0-1 vs >1, only perfusion asymmetry was significantly different between the groups. Breaking down the groups into single mRS scores reveals that ADC volume did increase as expected with higher mRS, but only changed significantly with an mRS of 4. Perfusion asymmetry, conversely, showed significant changes for an mRS of 1 and 4 compared to mRS of 0 and trended towards significance with an mRS of 2. Also, it can be seen from Figure 1 that the mean asymmetry index decreases with increasing mRS score, but mean ADC volume means remain relatively steady across mRS scores. These results indicate that in this cohort DWI may only be predictive of severe future disability, and that PWI may be a better predictor for intermediate outcomes. However, this analysis omits several potentially confounding variables such as age, gender, and type of clinical management. With a cohort of 109 patients, it should be feasible to account for these variables, and incorporating this data remains a target for further investigation.

Conclusion: Perfusion weighted imaging may be a better indicator of future moderate functional deficit than diffusion weighted imaging. More work is needed to account for potential confounding variables so that the predictive power of perfusion and diffusion weighted MR imaging can be better understood.

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References: [1] Chatterjee et al, ISMRM 2014 poster #2045 [2] Carroll TJ, et al. Radiology 2003; 227(2):593-600 [3] Ostergaard L, et al. Magn Reson Med 1996; 36(5):715-25