Automated Analysis of MR Perfusion Images Using a Vascular Territory Based Approach

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Purpose: MRI perfusion imaging has become a critical tool in the evaluation of ischemic cerebrovascular disease in both a clinical and research setting. When quantitative blood flow results are needed, a common technique is to have a physician manually draw ROIs in affected vascular territories and compare perfusion values to unaffected territories [1]. While this method has served fairly well for clinical diagnosis, which is usually not predicated on quantitative results, it presents several problems in a research setting. Manually drawing ROIs is time consuming and not standardized. It introduces bias, especially if the person drawing the ROIs is not completely blinded, and it makes large studies prohibitively time consuming. To attempt to address these concerns, we have developed an automated processing tool to evaluate regional ischemia in MRI perfusion scans and validated it on a cohort of patients with acute stroke.

Methods: 24 patients with acute stroke who received perfusion MRIs were identified by chart review at a single hospital. Areas of perfusion deficit were identified by a radiologist by visual inspection of MR perfusion images, and the corresponding affected vessels were confirmed by MRA, CTA, or x-ray DSA in 21 patients. In this group, there were 19 MCA strokes, 7 PCA strokes, and 7 ACA strokes (some had ischemia in multiple territories). Additionally, 10 healthy volunteers received identical DSC perfusion scans (13-15 slices of 5mm thickness, TR/TE 1500/45 ms, 128 x 128 matrix, 22 cm FOV, 30° flip angle, 50 measurements per slice) [2]. Perfusion images were reconstructed offline using automatic AIF selection [3] and SVD deconvolution [4]. All subjects received anatomical imaging for reference. Pre-contrast axial T1 scans were used when available, otherwise axial T2 or post-contrast T1 images were used.

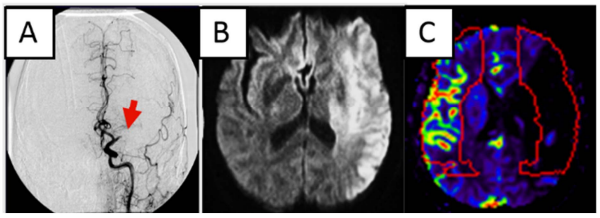

Figure 1: Angiogram, DWI, and perfusions images with generated ROI of superior branch of MCA

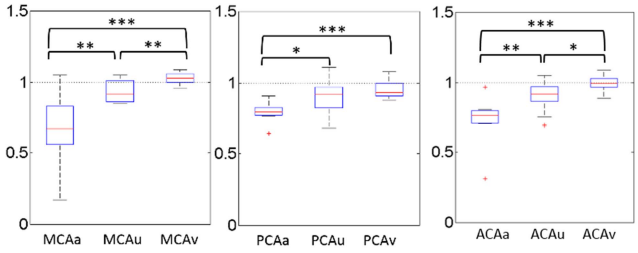

Figure 2: Boxplots of asymmetry index (lower=more asymmetry) in the MCA, PCA, and ACA for affected territories in patients (a), unaffected territories (u), and healthy volunteers (v). *p<.05; **p<.01; ***p<.001

	MCA	PCA	ACA
Affected	.68 ± .21 (N=19)	.79 ± .08 (N=7)	.72 ± .20 (N=7)
Unaffected	.94 ± .09 (N=5)	.91 ± .13 (N=17)	.90 ± .10 (N=17)
Volunteer	1.03 ± .04 (N=10)	.96 ± .07 (N=10)	.99 ± .05 (N=10)

Vascular territory ROIs were drawn by an interventional neuroradiologist on a single canonical image in MNI space. Territories were subdivided into regions perfused by major branches of the Circle of Willis, including the middle cerebral artery (MCA), posterior cerebral artery (PCA), and anterior cerebral artery (ACA). Cerebellar ROIs were omitted due to blooming artifacts and lack of coverage in many patients. These ROIs then served as a template for automatic construction of subject specific vascular territories.

For each patient, their anatomical reference image was coregistered with that patient's perfusion image. The reference image was then normalized to MNI space (SPM8), and the resulting parameters were used to invert the vascular template ROIs to create subject specific vascular territory ROIs. For each ROI, an asymmetry index was calculated by dividing the average perfusion in the ROI by the average perfusion by the same ROI on the other half of the brain (ipsilateral/contralateral for patients, left/right for volunteers). For a healthy subject, the theoretical index in an ROI is 1. All comparisons between groups used t-tests.

Results: Mean values in affected regions in patients (a), unaffected regions in patients (u), and volunteers (v) are shown in the table and plotted in Figure 2. All groups showed significantly lower indices in affected compared to unaffected regions (p<.05) and affected regions compared to normal volunteer (p<.001).

Discussion: Using a completely automated process, we calculated measures of perfusion asymmetry in territories supplied by major branches of the Circle of Willis. As expected, asymmetry was greatest in areas with confirmed ischemic stroke and smallest in healthy volunteers. Unaffected regions fell between these two, which may be attributed to low flow in watershed zones of adjacent ischemic regions. These results indicate that asymmetry indices created from an automated approach reflect true ischemia.

Conclusion: Automated construction of subject-specific vascular territory ROIs from a single pre-drawn template is a feasible method for rapidly analyzing MR perfusion images in an automated and unbiased way. Targets for further development are inclusion of cerebellar ROIs and reduction of blooming artifact through spin echo imaging.

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References: [1] Wintermark, et al. Stroke 2005; 32(5):294-314 [2] Srour JM, et al. J Cereb Blood Flow Metab 2011; 31(5):1272-82 [3] Carroll TJ, et al. Radiology 2003; 227(2):593-600 [4] Ostergaard L, et al. Magn Reson Med 1996; 36(5):715-25