Diffusion Lesion Characteristics after Thrombolysis Treatment in Ischemic Stroke

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Target Audience: Researchers and radiologists interested in ischemic stroke and quantitative diffusion neuroimaging.

Purpose: The efficacy of the thrombolysis treatment in arresting ischemic stroke lesion evolution may be analyzed by comparing the diffusion lesion volume before and after treatment. Multiple automated segmentation approaches [1-5] have been proposed for delineating the diffusion lesion in the acute phase of the ischemic stroke. The same algorithms may not be effective for segmenting the diffusion lesion on the diffusion-weighted imaging (DWI) data obtained one day after treatment (day 1 diffusion lesion). In this work, we analyze the diffusion lesion's apparent diffusion coefficient (ADC) and DWI characteristics after thrombolysis treatment and compare them with the diffusion lesion characteristics within 4.5 hours of ictus (day 0 diffusion lesion). We also analyze the sensitivity and specificity of different linear classification methods [6] in segmenting the day 1 diffusion lesion using Receiver Operating Characteristic (ROC) analysis.

Methods: *Imaging:* 65 ischemic stroke patients were imaged using a 1.5T GE Signa HDx MR scanner and an 8-channel head coil with DWI before thrombolysis treatment within 4.5 hours of stroke onset and approximately 24 hours after treatment in the anterior circulation of Sainte-Anne Stroke unit, Paris. Imaging parameters for DWI include: echo-time (TE) = 81-102, repetition-time (TR) = 6400-6675ms, flip-angle (FA) = 90°, Number of Averages (NEX) = 2, Acquisition matrix=128×128, Field-of-View (FOV) = 240×240mm^2, slice thickness of 6 mm, no gap, b=0 and 1000 s/mm2, diffusion encoding along axial, sagittal and coronal directions. A senior radiologist manually delineated bright lesions on day 0 and day 1 DWI images using the READY View software application [7] (Advantage Workstation; GE Healthcare) ensuring that no area of T_2-shine through effect was included by visual inspection of ADC maps. These reference lesion delineations were used in the ROC analysis. Lesion delineation in a representative day 1 case is shown in Figure 1. All the infarcts analyzed in this work are cerebral infarcts. *Mask generation*: An atlas based approach was used to segment the brain region into cerebrum and cerebellar regions. *ROC Analysis*: The DWI intensities in the cerebrum of each subject were normalized with the 98th percentile of the cerebrum's DWI intensity to generate nDWI. ADC values and nDWI intensities within the infarcts of the 65 subjects were combined to form a cumulative two dimensional (2D) histogram for the cohort. Similarly, the cumulative 2D histogram for cerebral regions outside of infarct (normal tissue) was also generated. The sensitivity and specificity of the different linear classifiers ADC ≤ tanα × nDWI + *n* (where tanα is the slope and *n* is the intercept of the linear classifier) was determined using ROC analysis for both day 0 and 1.

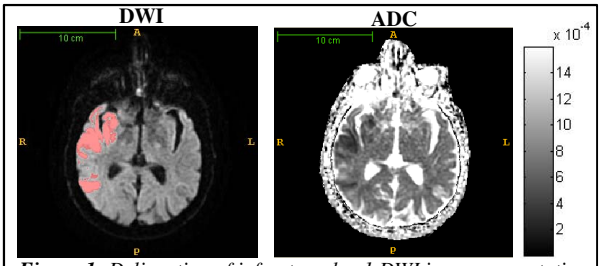

Figure 1: *Delineation of infarct on day 1 DWI in a representative case. The corresponding ADC map (mm^2/s) is also shown.*

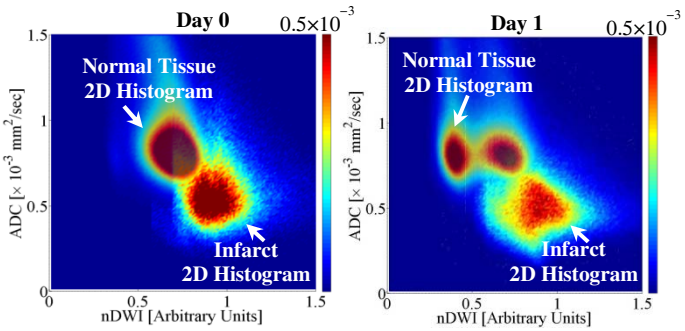

Figure 2: *Comparison of 2D Histogram of the infarct and normal tissues in 65 subjects for day 0 and day 1. ADC [×10^{-3} mm^2/s] and nDWI are the two dimensions for the 2D histogram. Color bar shows % counts. The distribution of ADC and nDWI shows dual peak for the normal tissue for day 1, possibly due to elevated intensity in some regions on DWI due to T_2-shine through.*

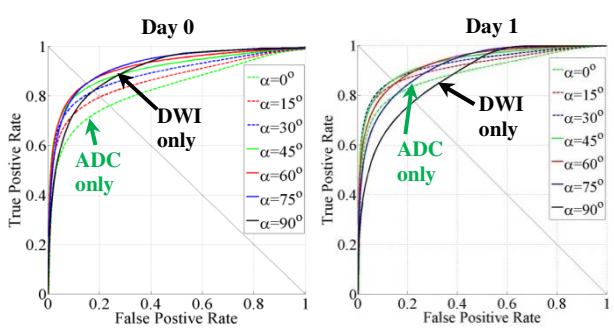

Figure 3: *ROC curves showing the sensitivity and specificity of different linear classifiers (ADC ≤ tanα × nDWI + n for α<90°; nDWI ≥ n for α=90°) in classifying the diffusion lesion. Classifier with α=0° is ADC only based classification and α=90° is DWI only based lesion classification.*

Results and Discussion: Figure 2 shows the differences in the distribution of ADC and nDWI values in the infarct and normal tissue regions for day 0 and 1. ROC analysis (Figure 3) shows the sensitivity and specificity of different linear classifiers in segmenting diffusion lesions on day 0 and day 1. At a particular value of α for the linear classifier ADC ≤ tanα × nDWI + *n*, different intercepts (*n*) generate the different points on the ROC curve. It can be observed that, in general, using both ADC and DWI improves the sensitivity and specificity in lesion classification for both day 0 and day 1 compared to using either of them alone. However, as shown in Figure 4, the optimal α for the linear classifiers (ADC ≤ tanα × nDWI + *n*) is different for day 0 and day 1. At 98% specificity, the sensitivity that can be achieved for day 1 diffusion lesion classification (~65%) is greater than the sensitivity achievable in day 0 diffusion lesion classification (~60%).

Conclusions: The optimal α for diffusion lesion classification in day 1 is smaller than optimal α for day 0 lesion classification, implying more reliance on ADC values than DWI intensity in day 1 diffusion lesion segmentation. At specificities greater than 95% an α of approximately 20º is optimal for day 1 diffusion lesion segmentation as compared 50º for day 0 diffusion lesion segmentation.

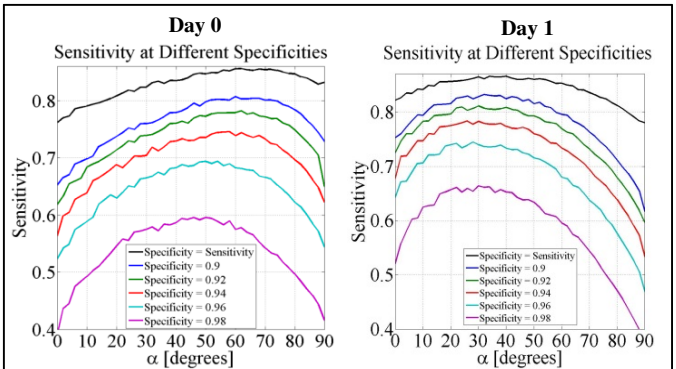

Figure 4: *Sensitivity achieved at a given specificity for different linear classifiers in segmenting diffusion lesion in day 0 and day 1.*

References: [1] Straka M et al, JMRI 2010; 32:1024–1037. [2] Lansberg M et al, Stroke 2011; 42: 1608-1614. [3] Nath SK et al, ISMRM 2010: p. 678. [4] Nargenthiraja K et al, ISMRM 2012: p. 756. [5] Montiel N et al, Acad Radiol 2008; 15:77–83. [6] Chebrolu et al, ISMRM 2013: p. 2984. [7] http://www3.gehealthcare.in/en/products/categories/advanced_visualization/applications/ready_view