Analysis of diffusion values for automated segmentation of stroke infarct

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Introduction: Accurate determination of stroke volume on diffusion imaging underpins all MR methods currently in use to screen candidates for reperfusion therapy, notably according to the perfusion diffusion mismatch model[1]. Routine use of this method is hindered by the time and expertise demand on lesion delineation. Automatic segmentation of stroke volume is highly beneficial for timely treatment decision. In addition, lesion delineation is useful even after treatment since the final infarct volume is correlated with of functional outcome.

Conventionally, diffusion weighted images are used to delineate stroke infarct. Prior work has indicated that lesion estimates are more reliable and reproducible with the use of Apparent Diffusion Coefficient (ADC) maps compared to diffusion weighted imaging (DWI)[2]. Recent automated segmentation algorithms are using ADC[3,4] or joint ADC and DWI[5] based approaches for automatic stroke infarct segmentation. The performance of these algorithms is dependent on the thresholds set on ADC values to separate the infarcted and normal tissue. Understanding the distribution of ADC values and DWI intensities in healthy and infarcted tissue is crucial for optimizing thresholds used. Here we report the statistical analysis of ADC values and DWI intensities in 62 patients imaged at the onset and 24 hours after the acute ischemic stroke event. From these analyses, we present optimal thresholds for automated segmentation.

Methods: 62 stroke patients were imaged with DWI before (Day 0) and 24 hours (Day 1) after treatment with thrombolysis according to rt-PA guidelines (< 4.5 hours after onset) on a 1.5 T GE scanner (Signa HDx, GE Healthcare, Chalfont St Giles, UK) with an 8-channel head coil. The imaging parameters include: TE/TR = 81-102/6600 ms, FA = 90°, NEX=2, Acquisition matrix = 256×256, FOV = 240×240 mm^2, slice thickness of 6 mm, no slice gap, b = 0 s/mm^2, and b = 1000 s/mm^2 diffusion encoding along axial, sagittal and coronal directions. A senior radiologist manually delineated the stroke infarct on DWI images of 62 patients for Day 0 and of 50 patients for Day 1 to obtain 3D infarct ROIs using the READY View tool within the Advantage Workstation platform (GE Healthcare, Buc, France). ADC values and DWI intensities within these ROIs were compared to the rest of the cerebrum and optimal thresholds for separating the two tissues were obtained after analysing the distributions using receiver operating characteristic (ROC) curves. The DWI data of each subject was normalized with an intensity corresponding to 98th percentile in the distribution of DWI intensities of that subject before performing the ROC analysis. Contrast was computed in each case as (mean of normal – mean of infarct)/(mean of infarct + mean of normal).

Table 1: *Summary statistics from histogram and ROC analysis*

	ADC (×10^{-3} mm^2/sec)		DWI (normalized)	
	Day 0	**Day 1**	**Day 0**	**Day 1**
Optimal Threshold	0.745	0.755	0.415	0.435
Infarct Tissue (Mean ± SD)	0.64 ± 0.20	0.64 ± 0.23	0.44 ± 0.13	0.50 ± 0.22
Normal Tissue (Mean ± SD)	0.90 ± 0.23	0.90 ± 0.22	0.29 ± 0.09	0.27 ± 0.10
Contrast	0.166	0.171	-0.200	-0.295

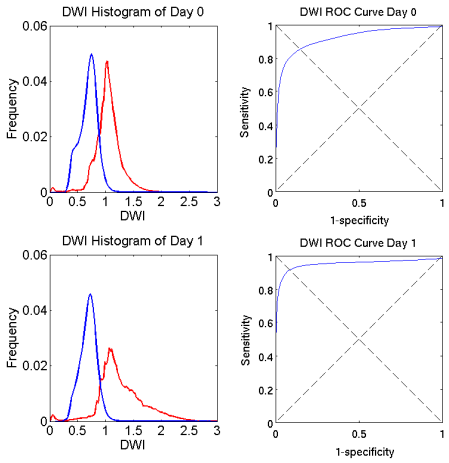

Figure 1*: Normalized DWI histograms of normal (blue) and infarcted (red) tissue along with (ROC) curves for Day 0 (top row) and Day 1 (bottom row).*

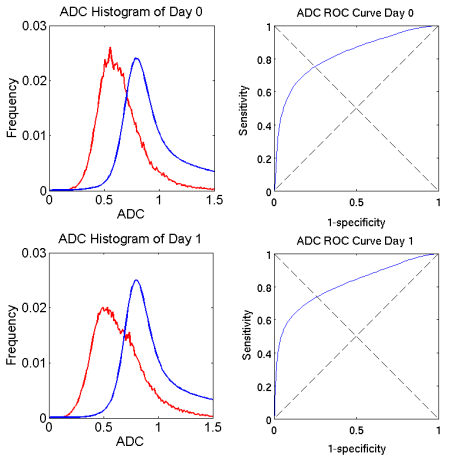

Figure 2*: ADC histograms of normal (blue) and infarcted (red) tissue along with ROC curves for Day 0 (top row) and Day 1 (bottom row).*

Results and Discussion: The contrast between infarcted and normal tissue was better for Day 1 than Day 0 for both DWI and ADC (Table 1). Although DWI displays high contrast between infarcted and normal tissue, contrast may be non-specific within the first few hours after stroke onset and is limited in cases such as leukoaraiosis[7]. In such cases, though ADC has lower contrast between infarct and normal tissue, it provides better specificity. ROC analysis shown in Figure 1 and Figure 2 demonstrates that normal and infarcted tissues are more separable using DWI than using ADC. To maximize the sensitivity and specificity, we suggest an ADC threshold of 0.745 and 0.755 for Day 0 and Day 1 respectively, for optimal separation between normal and infarcted tissues.

Conclusions: There was significant overlap between infarct and normal tissue for both ADC and DWI distributions. Hence, use of spatial constraints and post-processing would be required in addition to the use of optimal thresholds derived from ROC analysis, for generating automated contours for the stroke lesions.

References: [1] González RG et al, Radiology 210:155–62 (1999). [2] Rana A et al, 21:617-624 (2003). [3] Straka M et al, JMRI 32:1024–1037 (2010). [4] Montiel N et al, Acad Radiol 15:77–83 (2008) [5] Nath SK et al, ISMRM 2010: p. 678. [6] Shanbhag DD et al International Stroke Conference 2011, Abstract: 3217. [7] Helenius J et al, Stroke 33: 45-50 (2002).