

Incorporating ADC Temporal Profiles in Acute Stroke to Predict Ischemic Tissue Fate

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INTRODUCTION The mismatch between the perfusion and diffusion abnormality – widely considered to approximate the ischemic penumbra – indicates tissue at risk for infarction but potentially salvageable [1]. The perfusion-diffusion mismatch has been utilized to guide thrombolytic therapy and offers predictive value of ischemic tissue fate. Quantitative predictive models have employed multiple acute MRI parameters [2]. These predictive models, however, have been limited to using data from only a single time point. In principle, temporal evolution of ADC should help to improve prediction accuracy. For example, tissue with mild ADC reduction followed by further ADC reduction will be more likely to infarct than not, whereas tissue with mild ADC reduction followed by ADC returning toward normal value at a subsequent time point will likely recover. In this study, we propose a novel approach to incorporate the temporal profiles of acute ADC changes to characterize tissue fate based on a pixel by pixel basis. Analysis was performed on rat stroke models subjected to permanent, and 60-min middle cerebral artery occlusion (MCAO).

METHODS Male Sprague-Dawley rats were subjected to 60-min ($n = 12$) and permanent ($n = 10$) intraluminal middle cerebral artery occlusion (MCAO) [2]. Quantitative perfusion, diffusion and T_2 image data were acquired every 30 minutes during the acute phase up to 180 mins post-ischemia, immediate after reperfusion for reperfusion group, and again at 24 hours followed by histology. Image data were co-registered across multiple time points. Time course from each pixel were analyzed and grouped into similar temporal components via k-means clustering method using 30-min ADC only or ADC of all time points. The fate of each pixel (normal versus infarct) was determined using automated ISODATA analysis [3] of ADC, CBF and T_2 endpoint imaging (3 hrs in permanent MCAO, 24 hrs in 60-min MCAO). ADC temporal patterns with similar temporal characteristics were grouped together into 4 apparent components. ADC values for these components were plotted versus time after stroke onset. Tissue outcome (normal or infarct) for each component was analyzed.

RESULTS Permanent and 60-min group results are shown in **Fig.1** and **Fig. 2**, respectively. ADC maps of different time points were shown on top row and followed by ISODATA clustering method determined final infarct and k-means clustering map (using all time points). For both groups, there were four apparent temporal clusters. The time courses of averaged ADC for these clusters are shown below the images. The numbers at the right side of the time courses are the percentage of each cluster becoming infarct at end point. For instance, 96% of the tissues in red cluster of the permanent group clustered with 30-min data became infarct at end point.

For permanent MCAO group (**Fig.1**), the percentage to infarct of the red and yellow clusters clustered with single or multiple time points were similar. But, using multiple time points, the percentage to infarct of blue and green clusters were significantly lower than those of using single time point, which demonstrated improved clustering of survival tissue.

For 60-min MCAO group (**Fig. 2**), using multiple time points, an ADC monotonically decreasing cluster (red) was clustered and with almost 100% certainty that tissues in this cluster went to infarct at the end point. The percentage to infarct of the yellow cluster was also improved when using multiple time points.

DISCUSSION & CONCLUSION

The k-means clustering using multiple time points proved to be superior to using a single time point as increasing the certainty of clustering. This study presents a novel analysis approach that utilizes the ADC temporal characteristics to characterize ischemic tissue fate. We identify distinct temporal patterns that determined tissue salvageability. The key finding is that identifying tissue destined for infarction or tissue at risk based on an ADC threshold at a single time point is inaccurate, while utilizing information from multiple time points increases accuracy. Future studies will include CBF data and incorporating these results into predictive model [4-6]. Incorporating the ADC temporal characteristics in acute stroke should improve prediction accuracy. Although the ability to image multiple time points in acute stroke patients may be less practical, this approach should be helpful in animal studies. The knowledge gained will ultimately help clinical decision making in the treatment of stroke.

REFERENCES [1] Kidwell et al, Stroke 2003, 34:2729. [2] Shen Q, et al., JCBFM 2004; 24:280. [3] Shen Q, et al, JCBFM 2004; 24:887. [4] Wu O, et al. Stroke. 2001; 32, 933. [5] Shen Q, et. al., JCBFM 2005, 25: 1336. [6] Shen Q et al., NMR Biomed. 2008; 21:839.

