Reversal of abnormal ADC lags reperfusion and does not necessarily represent tissue salvage

H. An¹, A. L. Ford², K. D. Vo³, W. J. Powers⁴, J.-M. Lee⁵, and W. Lin⁶

¹Radiology, University of North Carolina at Chapel Hill, Chapel Hill, NC, United States; ²Neurology, Washington University in St. Louis, St. Louis, MO, United States; ³Radiology, Washington University in St. Louis, St. Louis, MO, United States; ⁴Neurology, University of North Carolina at Chapel Hill, Chapel Hill, NC, United States

Introduction

Magnetic resonance diffusion weighted imaging (DWI) is widely utilized in clinical practice to depict acute ischemic stroke lesions. It has been demonstrated that compromised blood flow leads to a reduction in the apparent diffusion coefficient (ADC) during ischemia. Conversely, DWI lesions have been found to reverse after thrombolysis. The temporal behavior of ADC lesion reversal after reperfusion during the first hours after stroke onset has not been documented in humans. Moreover, it has not been thoroughly investigated whether the perfusion status at the time of or subsequent to an abnormal ADC measurement affects the final fate of tissue. To this end, a sequential MR imaging study was performed in human stroke in order to examine the temporal evolution of reduced ADC in specific brain regions with different perfusion characteristics. Risk of infarction was measured and compared.

Methods

Thirty-one participants were serially scanned with a 3T whole body Trio system MRI (Siemens) at 3 time points (tp): within 3.5 hours (tp1), at 6 hours (tp2), and at 1 month (tp3) after stroke onset. Imaging protocols, including DWI, FLAIR and dynamic susceptibility contrast (DSC) PWI were performed at both tp1 and tp2. FLAIR images acquired at tp3 were used to manually delineate the final lesion. Image registration was performed to align all images acquired at different time. Hyperperfusion was defined as MTT > 4 seconds longer than the mean contralateral hemispheric. Voxels with ADC values < mean-2*SD of the contra hemisphere were defined as abnormal. Based on the MTT at tp1 and tp2 and ADC at tp1, three regions of interest (ROIs) were defined (Figure 1): ROI(1) abnormalADCtp1_reperf3hr, exhibiting abnormal ADC at tp1 and normal MTT at both tp1 and tp2, suggesting regions with abnormal ADC caused by earlier ischemia was reperfused prior to tp1 (<3 hours); ROI(2) abnormalADCtp1_reperf6hr, exhibiting abnormal ADC and MTT at tp1, and normal MTT at tp2, suggesting ischemia with reperfusion between tp1 (3 hours) and tp2 (6 hours); and ROI(3) abnormalADCtp1_nonreperf, exhibiting abnormal ADC at tp1 and abnormal MTT at both tp1 and tp2, representing ADC lesions with persistent hypoperfusion. In all ROIs, isolated regions smaller than 1 ml were removed to minimize artifacts due to misalignment. ADC values from all three ROIs were obtained to examine the temporal evolution trend from tp1 to tp2. To assess the effect of reperfusion status (reperfusion <3hr, reperfusion 3-6 hr, and without reperfusion) on an initially abnormal ADC region, a generalized linear model (SAS 9.2) was utilized to perform an analysis of covariance (ANCOVA) to evaluate whether reperfusion and/or tp1 ADC values might affect ADC change from tp1 to tp2 (ΔADC=ADC tp2-ADC tp1) in all three ROIs. One-way analysis of variance (ANOVA) with Newman-Keuls multiple comparison post test was performed to evaluate whether the risk of infarction differed among all three ROIs.

Results

ROI(1) abnormalADCtp1_reperf3hr, representing hyperacute reperfusion (< 3 hours), were identified in 12 subjects. From tp1 to tp2, MTT were normal, while the abnormal ADC lesion reversed from tp1 to tp2 (ΔADC=ADC tp2-ADC tp1) in all three ROIs. One-way analysis of variance (ANOVA) with Newman-Keuls multiple comparison post test was performed to evaluate whether the risk of infarction differed among all three ROIs.

Discussion and Conclusions

This study focused on elucidating the temporal relationship between perfusion and ADC utilizing two sequential MR scans during hyper-acute stroke (within 3 hours and at 6 hours). We found a temporal dissociation between ADC change and perfusion alterations, with ADC changes lagging behind reperfusion. In this study, we also assessed how different perfusion characteristics affect the predictive value of low ADC for the risk of infarction. We found that ADC recovery subsequent to reperfusion does not necessarily predict tissue salvage.

References