Correlation of ADC Decreases and Perfusion MRI Parameters in the Ischemic Core of Acute Stroke Patients

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Introduction

Diffusion weighted MR imaging (DWI) detects acute ischemic tissue within minutes after stroke onset[1]. In clinical stroke, DWI signal changes reflect tissue unlikely to recover. Ischemic cell depolarization and water shift from extracellular to intracellular space is thought to be the main contributor to DWI signal changes in acute ischemic lesions. The water shift is quantified by calculation of the apparent diffusion coefficient (ADC) DW images. Perfusion weighted MR imaging (PWI) semi-quantitatively measures tissue perfusion and in combination with DWI enables the characterization of tissue at risk of infarction. Animal studies found a correlation between the decrease of ADC values and metabolic and hemodynamic parameters[2]. Whereas ADC decreases below 77% indicated the ischemic core (ATP depletion), ADC values around 90% of normal corresponded with acidic but still viable tissue (anaerobic glycolysis).

On the background of these findings we hypothesized, that the ADC decrease should correlate with the severity of the perfusion deficit in acute stroke patients (<6h). Markedly decreased ADC values in the ischemic core should correlate with a severe perfusion deficit, whereas ADC should tend towards normal values at the rim of the ischemic tissue with the perfusion deficit becoming successively smaller. We were particularly interested to find out which perfusion-parameters would show the best correlation with the ADC values.

Subjects and Methods

We enrolled 8 Patients with sudden onset of neurological deficits during the last 6 hours with a precise determinable onset. Informed consent was obtained. All MRI scanning was performed on a 1,5 T clinical whole body scanner Magnetom Vision Plus (Siemens, Erlangen, Germany) using a standard head coil. The measurements included an axial DWI Sequence, a FLAIR Sequence, a PWI sequence and a MRA. The whole protocol was performed in less than 20 minutes. All MR studies were run in corresponding slice positions (commisura anterior/posterior). The anisotropic DWI sequence acquired 19 slices with a distance factor of 0.10, field of view (FOV) 230 mm acquisition, a matrix of 96x128 Pixels, TE 100 ms, TR 4s). PWI (bolus tracking) was performed with 11 slices, thickness of 5 mm, interslice gap of 1.64 mm, FOV 230 mm, a matrix of 128x128 Pixels, TE 29 ms, TR 1.5 s.

Postprocessing of the image data was performed using custom written software (MRVision, Menlo Park, CA) on a Sun Ultra SPARC Workstation. A gammavariate fit was applied to compute parameter images for maximum of signal drop (Peak), time to peak (TTP), relative cerebral blood volume (rCBV), relative cerebral blood flow (rCBF), relative mean transit time (rMTT).

A threshold function was used to identify tissue areas with decreased ADC values at steps of 10% of the normal control hemisphere in each single slice. Pixels with ADC decreases in the range of <50%, 50-60%, 60-70% and 70-80% were integrated and transferred to the PWI parameter maps. An unpaired t- test (two- tailed) was used to evaluate significant differences (p<0.05) between the different perfusion parameters in areas of successive lower ADC in for all subjects. Correction for multiple testing was performed.

Results

The mean ADC value of the unaffected hemisphere (averaged over 11 slices) was $787+-30 \times 10^{-3}$ mm^{-2} s^{-1}. All patients revealed a PWI>DWI mismatch. There was an "onionskin- like" distribution of successively decreased ADC values with the lowest ADC in the center of the ischemic area. (Fig.1.). Accordingly, the most severe perfusion deficits with stepwise decreases in peak, rCBF and rCBV parameter values were located in the ischemic core region. This effect was most pronounced in the TTP maps (Fig.2.). ADC decreases were significantly correlated with an increase of TTP. Peak, rCBV and rCBF similarly revealed a stepwise decrease.
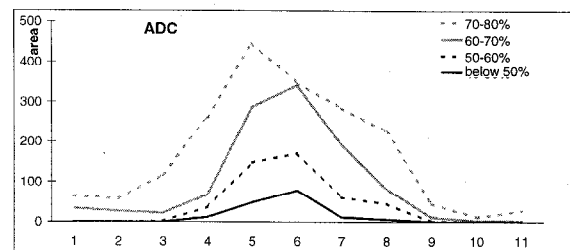

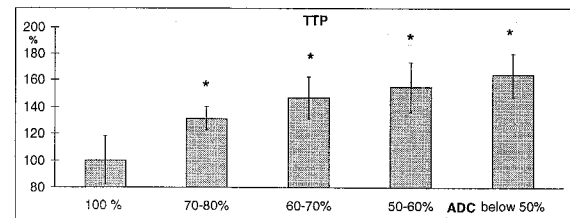**Fig.1.** Onionskin-like distribution of areas with progressively reduced ADC values

Fig.2. Correlation of TTP delay with ADC thresholds (mean ± SD, p<0.05).

Discussion

Animal studies suggested that the ADC decrease as indicator of tissue viability is a function of duration and severity of the perfusion deficit[2]. We were able to show that a similar correlation can be found in clinical stroke lesions. The severity of the perfusion deficit in the initial hours after stroke onset obviously determines the dynamics of the ADC decrease. In line with other investigators[3], the TTP maps turned out to be the most robust parameter for a stepwise estimation of the perfusion deficit, although a decrease in peak, rCBF and rCBV reliably labeled the core of the ischemic area.

Monitoring the regionally matched PWI/DWI-parameters during stroke progression could improve our ability to determine prognosis in regional tissue viability.

References

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3. Neumann-Haefelin-T et al. Stroke. 30(8): 1591-7. 1999