

ADC values in the corticospinal tract at the acute stage can help predict stroke outcome

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Background:

Previous studies have used Diffusion-Weighted Imaging (DWI) to look for predictors of outcome in acute stroke patients. DWI lesion volumes assessed in the first six hours of stroke onset (H6) and at one day (D1) have been proposed as predictors of stroke outcome¹ but its accuracy is insufficient for an individual prediction, in a clinical environment². DWI lesion patterns, such as border zone infarcts, were also associated with poor outcome³, suggesting that lesion localization may be more efficient than lesion volume to predict stroke outcome. ADC maps provide more information on tissue damage than DWI. Reduction in the apparent diffusion coefficient (ADC) values corresponds to ischemic changes and could help better identifying irreversible damages than DWI signal changes. In this study, we used diffusion imaging at the acute stage to look for predictors of clinical outcome in a group of 76 stroke patients. Our hypothesis was that location of infarction at the acute stage was crucial in predicting stroke outcome. We also tested the hypothesis that ADC values in the corticospinal tract (CST) at H6 and D1 can identify patients with good and poor outcome.

Material and Methods:

ADC maps were generated from DWI acquired at 1.5-T in acute stroke patients examined within the first six hours of stroke onset and with a follow-up DWI at day one. Stroke outcome was assessed at three months by the modified Rankin Scale (mRS) and good outcome was defined by a mRS 0 and 1. ADC maps were normalized into the MNI T2 template.

First, SPM analysis (SPM5 package) was performed to find key regions associated with poor outcome using ANCOVA with age as a confounding variable (height threshold $p < 0.0001$) at H6 and D1. Clusters were superimposed on a CST template for interpretation⁴.

Then, for individual prediction, ADC values in the CST template were measured for each slice in each patient. For each slice, we automatically classified patients based a simple univariate classification assigning each subject to the closest group. Thus, for each slice we obtained an ADC cut-off value and a classification accuracy. Robust accuracy estimates were computed using a Bootstrap approach.

Results:

Twenty-seven patients (mean age: 56 years, mean baseline NIHSS: 10) with good outcome at 3 months (mRS 0-1) and forty-nine patients (mean age: 63 years, mean baseline NIHSS: 17) with poor outcome (mRS 2-5) had an initial DWI/ADC map in the first six hours of stroke onset (mean time to MRI: 2.6 hours) and a follow-up MRI at day one (mean time to follow-up MRI: 1.2 days).

At H6 in the poor outcome group, there was a reduction in ADC values involving the inferior part of the lenticular nucleus close to the origin of the lenticulostriate arteries of the middle cerebral artery (MNI coordinates: 28 -8 -6, T-score: 3.33). At D1, the significant cluster was located in the internal capsule and the lenticular nucleus and overlapped with the CST template (MNI coordinates: 26 -8 24, T-score: 5.34) (Figure 1).

In the individual prediction, ADC values in the CST template of the good outcome group differed from those of the poor outcome group at day one for slices located between $z=14$ and $z=36$ and at H6 for the slices between $z=34$ and $z=46$ (MNI coordinates, $p < 0.05$). An ADC cutoff value of $671 \times 10^{-6} \text{ mm}^2 \cdot \text{s}^{-1}$ (at z -coordinate 20) could classify patients in the good or poor outcome group with 65% of accuracy at H6; at D1, the ADC value of $658 \times 10^{-6} \text{ mm}^2 \cdot \text{s}^{-1}$ (at z -coordinate 28) reached this classification with 71% of accuracy.

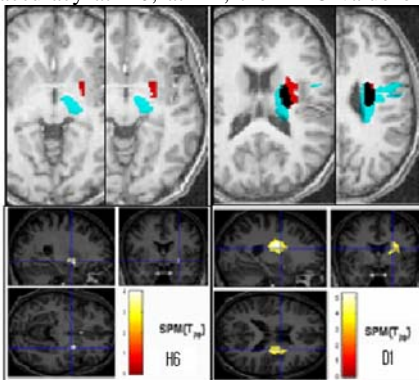


Figure 1.

Figure 1: Left: Area of decreased ADC value in the SPM comparison of the good versus poor outcome group (red) and the CST template (blue) at H6 (Left) and D1 (Right) superimposed of the T1-anatomical images.

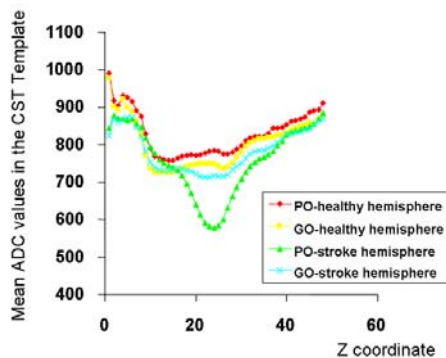


Figure 2.

Figure 2: Mean ADC values in the CST along the z direction (MNI) at D1. PO is the poor outcome group and GO is the good outcome group. ADC values were significantly lower in the PO group (green) than the GO group (blue) in the stroke hemisphere.

Conclusion:

Patients with poor outcome (mRS 2-5) had a CST damage (marked ADC reduction) in the first six hours of stroke onset and at day one. ADC values in the CST were significantly lower in the poor than in the good outcome group at both stages. ADC values in the CST can help individually classify patients according to stroke outcome with 65% accuracy at H6 and 71% at D1. Further analysis will help determine if multivariate models with DWI, penumbra volumes or clinical covariates increase the accuracy of these models in the prediction of stroke outcome at the acute stage, especially in the first six hours of stroke onset.

References

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4- Bürgel et al, NeuroImage, 2006;29:1092-1105.