Apparent kurtosis and fractional anisotropy potentially predicts tissue outcome in sub-acute stroke

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Introduction

In acute to early subacute middle cerebral arterial stroke, the mean diffusivity (MD) is more reduced in white matter (WM) than in gray matter (GM) [1]. Moreover, the temporal evolution of MD and fractional anisotropy (FA) is different for WM and GM with varying degree of WM damage at three months [2]. The apparent diffusion kurtosis (ADK) has previously been proposed for visualization of non-Gaussian diffusion [3]. Changes in kurtosis, determined in repeated diffusion weighted (DW) measurements using different diffusion times (T0), reflect altered micro-structural tissue properties in subacute stroke [4].

Our aim was to evaluate the potential of MD, FA and ADK to predict tissue outcome in WM and GM immediately after stroke onset with measurements performed three months after stroke onset used as reference.

Method

Two patients were studied, both with subacute ischemic stroke involving WM and GM, with WM involvement encompassing the deep white matter (Fig 1a, 1c, 1d, shown by small white arrows) as well as the subcortical U-fibres (Fig 1a, 1c, 1d, shown by the large white arrow). Measurements were performed 2, 9 and 90 days after stroke onset at a Philips 3T Achieva scanner, using six diffusion encoding directions. Signal-versus-measurements using different diffusion times (three months after stroke onset used as reference.

Under guidance of T2-weighted (T2W) images acquired day 2 after stroke onset, tissue in the infarcted area was labelled WM or GM. Tissue outcome was determined using T2W images from day 90; WM was either appearingly normal (WMnormal) or showed increased signal intensity as in gliosis (WMgliosis), while GM showed gliosis in all parts of the infarcted area. For each time point of investigation, twelve regions of interest (ROI) were placed in each tissue type. For comparison T2-values were obtained from the same ROIs as well as from ROIs placed in the contralateral hemisphere and the ratio of lesion to contralateral normal tissue T2W signal intensity was determined. The difference in parameters estimated in WMnormal and WMgliosis was calculated for each time point and expressed in percent.

Result

At day 90, normal appearing WM was found in deep white matter (Fig 1a, 1c, 1d, shown by small white arrows), while development of gliosis was seen in the subcortical U-fibers (Fig 1a, 1c, 1d, shown by the large white arrow). The T2-ratios differed between tissue types at day 2 after stroke onset, at day 9 as well as day 90 (p < 0.0001) (Table 1). MD was similar in WMnormal and WMgliosis at day 2 after stroke onset, while FA and ADK for both T2 depended on tissue outcome (Table 1). The difference between WMnormal and WMgliosis in FA, ADK was 40% or more and persisted, although somewhat smaller, at day 90.

Table 1. Average values for each parameter, obtained from the patient shown in Fig 1. ADK and FA differed between WMnormal and WMgliosis at day 2, while MD did not.

<table>
<thead>
<tr>
<th>param</th>
<th>WM normal</th>
<th>GM ratio</th>
<th>FA Td30 gliosis</th>
<th>ADK Td30 gliosis</th>
<th>ADK Td60 gliosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 2</td>
<td>1.06 / 0.135</td>
<td>2.24 / 0.25</td>
<td>0.46 / 0.33</td>
<td>1.13 / 1.69</td>
<td>1.15 / 1.87</td>
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<tr>
<td>Day 9</td>
<td>1.15 / 1.35</td>
<td>0.67 / 0.59</td>
<td>0.29 / 0.17</td>
<td>0.71 / 0.75</td>
<td>0.70 / 0.72</td>
</tr>
<tr>
<td>Day 90</td>
<td>1.31 / 2.25</td>
<td>0.80 / 1.37</td>
<td>0.24 / 0.08</td>
<td>0.79 / 0.59</td>
<td>0.76 / 0.55</td>
</tr>
</tbody>
</table>

Discussion and conclusion

Tissue outcome in acute stroke is dependent not only on tissue type (WM or GM), but in WM also on location (deep WM versus subcortical U-fibres). In the subacute stage, MD cannot distinguish between WM that will pseudo normalize and WM that will progress to gliosis, but FA and ADK can. Furthermore, kurtosis obtained from two diffusion times shows an increase in non-Gaussian diffusion at day 2 in WMgliosis and GM, that becomes more Gaussian later, indicating tissue degeneration.

References