Case report

A new diffusion metric, diffusion kurtosis imaging, used in the serial examination of a patient with stroke

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Abstract

We report a case of a patient who developed a cerebral infarction, which was assessed using a new and advanced diffusion technique: diffusional kurtosis (DK) imaging. The signal changes on DK images were different from those on apparent diffusion coefficient (ADC) maps, and they seem to be useful for the prediction of early-stage tissue infarction. Although diffusion-weighted imaging and its metric, the ADC, have been widely used in the evaluation of stroke, DK imaging will provide additional and useful information, including a more detailed evaluation of pathologic tissue changes. This information can be predictive of the prognosis.

Keywords: Kurtosis, magnetic resonance imaging, stroke, diffusion-weighted imaging, apparent diffusion coefficient, non-Gaussian

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Diffusion-weighted imaging (DWI) and its metric, the apparent diffusion coefficient (ADC), have been widely used in the evaluation of lesion volume after stroke, outcome (including reversibility), and the estimation of onset time. Recently, a more advanced MR diffusion metric called diffusion kurtosis (DK) imaging was introduced (1), and preliminary results from DK imaging for the clinical investigation of brain disorders have been reported. To assess cerebral infarction, a preliminary report demonstrated the value of DK imaging for assessing stroke, including more details of pathologic tissue changes, such as axonal varicosities or alterations associated with the endoplasmic reticulum (2). Here, we report the case of a patient who developed a cerebral infarction in the right deep white matter, which was assessed by DK imaging.

Case report

A 40-year-old woman complained of headache and speech disturbance without motor dysfunction for the previous two weeks. An interview revealed that she had no history of disease. Brain MRI demonstrated multiple cerebral infarctions and a more subacute infarcted lesion in the right frontal deep white matter on DWI and the calculated ADC map (Fig. 1a and b). A corresponding mean DK image showed the peripherally high intensity and dark dot in the stroke lesion (Fig. 1c). Infarction in the left temporal cortex was also observed, which was thought to be the cause of the speech dysfunction (not shown). Moreover, MR angiography poorly depicted the bilateral middle and anterior cerebral arteries (not shown). The patient was ultimately diagnosed with Moyamoya disease. Two weeks later, repeated MR scanning revealed a homogenous high signal on both DWI and the ADC map (Fig. 1d and e) and partially normalized mean DK (Fig. 1f) in the corresponding ischemic lesion. In the FLAIR image taken 6 months later (Fig. 1g), the stroke lesion displayed a low signal in the central cystic portion with peripheral high intensity, as reflected in the DK image.

Discussion

The time courses of signals on DWI and ADC value changes are well-known. At the onset of stroke, an initial increase in the DWI signal and decreased ADC values were observed at the stroke lesion. However, the prediction of tissue reversibility is complex and difficult and involves use of DWI and the ADC. In general, lower ADC values indicate lower reversibility; however, there are a few reports indicating that severe decreases in the proportion of ADC tissue at the time of stroke are associated with recovery. One of the reasons for this association is that the clinical use of DWI

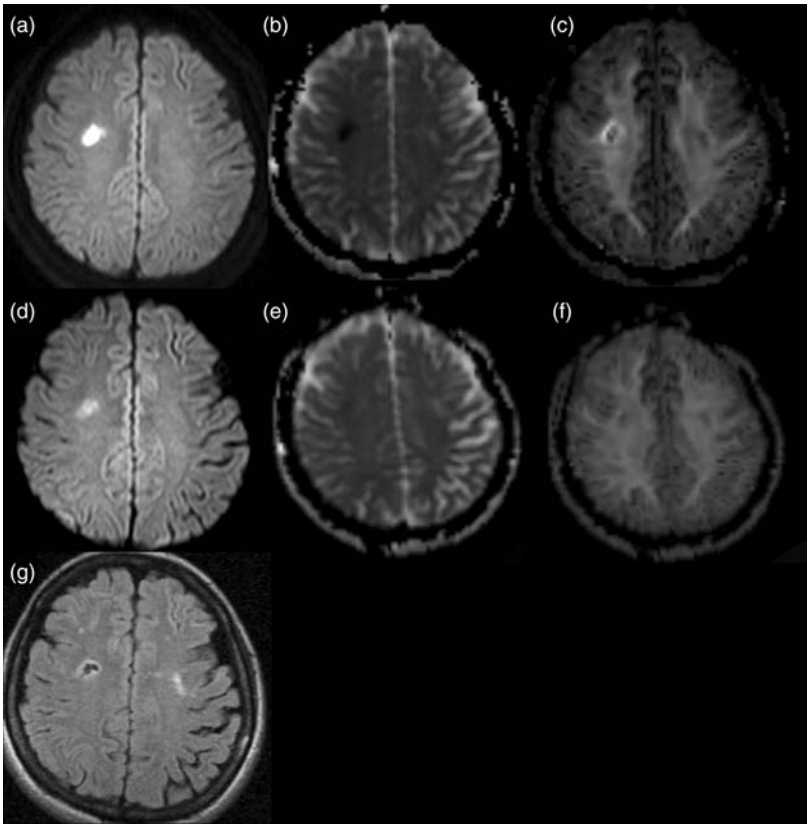

Fig. 1 MR imaging studies of the patient. Brain MRI demonstrated multiple cerebral infarctions, including a subacute lesion in the right frontal deep white matter, which appeared as a high signal on DWI and a low signal on the calculated ADC map (a, b). However, the corresponding mean DK image shows the peripherally high intensity and dark dot in the stroke lesion (c). The mean DK values for high intensity and dark dot are 1.596 and 0.591, respectively. Two weeks later, repeated MR scanning revealed a homogenous high signal on both DWI and the ADC map (d, e) and partially normalized mean DK (f) in the corresponding ischemic lesion. The mean DK value for the normalized area is 0.842. In the FLAIR image taken 6 months later (g), the stroke lesion revealed a low signal in the central cystic portion, with peripheral high intensity, as in the first DK image

and the ADC is theoretically based on the Gaussian distribution of water molecules. This assumption is not realistic *in vivo* because the neural tissues represent a complex environment in which the movement of water molecules is restricted. Moreover, conventional DWI with b values of $800 \sim 1000$ s/mm^2 has been thought to depict extracellular water movement only. Therefore, the value of ADC estimation for the purpose of tissue reversibility was limited (3). Recently, more advanced MR diffusion techniques and non-Gaussian diffusion-weighted imaging were introduced for use in the brain in the clinical context (2–4). DK imaging is a relatively easy method to implement because it is less demanding in terms of imaging time and gradient strength. The mean DK is thought to be an index of microstructural complexity, and it shows different and promising results as an additional biomarker for stroke (2, 4). One report (5) described greater increased mean DK values on day 2 in ischemic white matter. The situation in this patient eventually progressed to gliosis, indicating that the initial mean DK may be useful in predicting ischemic tissue outcome in combination with serial MR scanning of patients after stroke. The mean DK in ischemic white matter becomes progressively reduced, with mean DK pseudonormalization occurring between days 2 and 9, which represents an earlier DWI time course (5).

In this patient, initial DK imaging showed peripheral high intensity in ischemic areas, which supported later gliosis, as confirmed on a FLAIR image, notwithstanding homogenous decreases corresponding to the ADC value. The second DK image showed pseudonormalization occurring in the lesion, but this was not apparent on the DWI. Both DK images showed the core of the ischemic lesion as low intensity, indicating neural loss or cell death, as did FLAIR images taken over time.

In conclusion, larger studies will be needed; DK imaging will provide additional and useful information, including more detailed evaluations of pathologic tissue changes and predictions about the prognosis in stroke patients with infarcted lesions in the early clinical stages, as compared with conventional diffusion-weighted imaging and its metrics, such as the ADC.

Conflict of interest: None.

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