Leukoencephalopathy in acute CO intoxication: Diffusion kurtosis versus diffusivity

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Introduction

Carbon monoxide (CO) intoxication is one of the most common causes of poisoning related to brain damage. Persistent neurological sequela of delayed leukoencephalopathy is the primary syndrome occurred after acute CO intoxication, such as parkinsonism, motor impairments, cognitive and memory deficits [1-2]. Demyelination and disruption of the white matter are considered to be the main pathologic features of delayed leukoencephalopathy [3], implying the importance of early detection of the subtle changes in the white matter. Previous studies have reported that decreased FA of specific white matter was found in patients after acute CO intoxication, suggesting an occurrence of the white matter structural changes [4]. Recently, diffusion kurtosis imaging (DKI) has been proposed to characterize the non-Gaussian distribution of diffusion displacement resulting in higher sensitivity to the brain microstructure [5]. As a result, the purpose of this study is to evaluate the feasibility of using parametric indices derived from DKI for early detection of leukocephalopathy in patients with acute CO intoxication.

Method

11 subjects including 5 patients with acute CO intoxication within 7 days and 6 healthy volunteers were enrolled in this preliminary study. All the MR imaging was performed on a 3 T MR scanner (Discovery MR750; GE Healthcare, Milwaukee, WI, USA). In addition to the conventional imaging protocols, DKI data was obtained used two sequential spin echo diffusion-weighted 2D EPI images with b values of 0, 1000, and 3000 s/mm2 in 40 non-collinear directions. Other imaging parameters were as follows: TR/TE = 10000/110.5 ms, FOV = 240x240 mm^2, matrix size = 128x128 (zero-filled to 256x256), slice thickness = 4 mm, # of slice = 36, Asset= 2, BW = 1953.12 Hz/Pix, and total scan time less than 30 min. After data acquisition, a 2D median filter was performed first to alleviate the noise effect due to lower SNR of b3000 images. All the DKI images were used to calculate the DK-related parametric maps including axial, radial and mean kurtosis (MK). DT-related parametric maps were also derived from diffusion tensor model, including axial, radial and mean diffusivity, as well as FA maps.

Results

Results of the derived DT- and DK-related parametric maps from one patient with acute CO intoxication are shown in Figure 1. Although both MK and radial kurtosis maps showed better contrast between brain white matter and gray matter structure than the diffusivity maps, no significantly visual difference was found in these images. On the other hand, two ROIs in the regions of body and splenium of corpus callosum were selected for quantitative analysis by referencing the FA map (Figure 2). The mean and standard deviations of the DT- and DK-related parametric indices were displayed in Table 1. Significant difference of mean kurtosis was shown on body of corpus callosum in the patient with acute CO intoxication as compared to that in control subjects.

Discussion

This study demonstrated the feasibility of DKI method for early detecting the brain WM microstructure changes in patients with acute CO intoxication. Recently, several reports have demonstrated that MK, the average apparent kurtosis, could offer an improved sensitivity in detecting changes in neural microstructure as compared to conventional DTI method. In our preliminary result, a significantly decrease of MK in body of corpus callosum was observed, suggesting that diffusion kurtosis imaging could be a more sensitive biomarker than conventional DTI. On the other hand, variation in directional kurtosis map is somewhat higher than MK map, in which further investigation on more subjects is needed. To sum up, DKI could provide more information, such as directional and mean kurtosis maps, which may have potential to detects the early microstructural changes and helpful in predicting the possibility of leukoencephalopathy in patient with acute CO intoxication.

Reference

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Parametric indices	Patients (n=5)	Control subjects (n=6)	P
Body of Corpus Callosum			
MD (μm^2/ms)	0.95±0.05	0.96±0.08	0.878
D_{axial} (μm^2/ms)	1.94±0.10	1.95±0.20	0.931
D_{radial} (μm^2/ms)	0.46±0.06	0.46±0.09	0.936
FA	0.65±0.08	0.73±0.06	0.134
MK	0.85±0.03	0.99±0.07	0.010 *
K_{axial}	1.83±0.42	2.47±0.64	0.118
K_{radial}	1.61±0.30	2.06±0.49	0.137
FA_k	0.55±0.04	0.58±0.02	0.287
Splenium of Corpus Callosum			
MD (μm^2/ms)	0.93±0.05	0.96±0.07	0.453
D_{axial} (μm^2/ms)	2.06±0.08	2.06±0.07	0.900
D_{radial} (μm^2/ms)	0.41±0.07	0.42±0.09	0.847
FA	0.79±0.03	0.77±0.06	0.493
MK	1.01±0.05	1.07±0.10	0.311
K_{axial}	2.99±0.63	2.69±0.84	0.642
K_{radial}	2.45±0.29	2.64±0.84	0.668
FA_k	0.67±0.09	0.62±0.06	0.334

Table 1 Results of the DT- and DK-related parametric indices in patients with acute CO intoxication and control subjects.

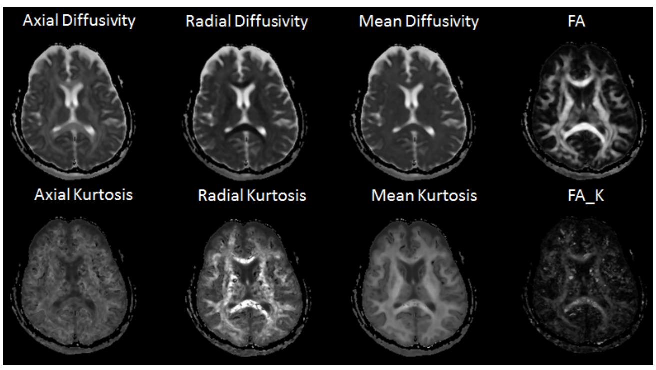

Figure 1 Images of the DT-and DK-related parametric maps from one patient with acute CO intoxication.

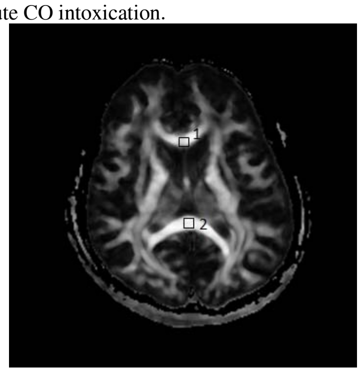

Figure 2 An illustration of ROI selections performed in this study.