Long-term evolution of multiexponential diffusion features in a model of transient Ischemia in rats

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Introduction

Numerous pathological changes, such as edema, axonal injury, loss of myelin, and breakdown of the microstructure follow ischemic stroke. Several groups have emphasized the important role of dynamic parameters such as membrane permeability, water exchange and cell size distribution(1). These parameters might be estimated using biexponential model. In the present work, in a rat model of transient middle cerebral artery occlusion (MCAO) we measured the temporal evolution of the exponential biexponential brain diffusion signal decay parameters (fast and slow apparent diffusion coefficient (ADC), ADC_{fast} and ADC_{slow} and fast and slow fraction f_{fast} and f_{slow}) from the hyperacute to chronic phase. For comparison we calculated also monoexponential apparent diffusion decay (ADC) curves. The aim is to evaluate the role of large b-value diffusion measurements in characterizing the ischemic damage in cerebral ischemia models. To our knowledge, there are no studies that have extensively monitor the evolution of biexponential diffusion parameters after brain ischemia model over long follow up periods.

Material and methods

MCAO was induced in Wistar rats (n = 9) by the intraluminal suture occlusion of the middle cerebral artery (MCA) for 90 min followed by reperfusion. The MRI measurements were repeatly performed (with a 4.7 T MR Scanner) at 2 and 3.5 hours, 1, 2, 3, and 4 days, 1, 2, 4, 6, and 8 weeks after the MCAO. Sham-operated rats were used as healthy controls (n = 8). Deep and subcortical white matter (WM) and cortical gray matter (GM) regions within the infarcts will be analyzed individually. Diffusion measurements were acquired from multi-shot spin-echo echo-planar image (EPI) with 3 directions (x,y,z) and 31 b values from 0 to 6000 s/mm^2.

Results

In healthy rats ADC_{fast} showed a significant difference between the cortex, subcortex, and corpus callosum ($p < 0.001$). f_{slow} showed a significant difference between the cortex and subcortex ($p = 0.01$). ADC_{fast} increased significantly, in the acute and subacute phases in corpus collasum, in the chronic phase in subcortex and in the subacute and chronic phases in cortex. ADC_{slow} increased significantly in chronic phase in subcortex. f_{slow} increased significantly in hyperacute phase in subcortx and corpus collasum and in hyperacute and acute phases in cortex (Fig.1).

Discussion

The study showed that healthy and ischemic brain tissues diffusion behavior could be presented by a biexponential, 2 compartments model, with fast and slow diffusion. ADC_{fast}, ADC_{slow}, and f_{fast} values obtained from intact brain tissues are in good agreement with the previous works (2, 3). ADC_{fast} show higher sensitivity compare to ADC_{slow} in characterizing ischemic tissue phases. In hyperacute phase the relative volume fraction of the slow component increased consistent with intracellular swelling. Biexponential analysis offers parameters which may help interpreting structural tissue changes.

References

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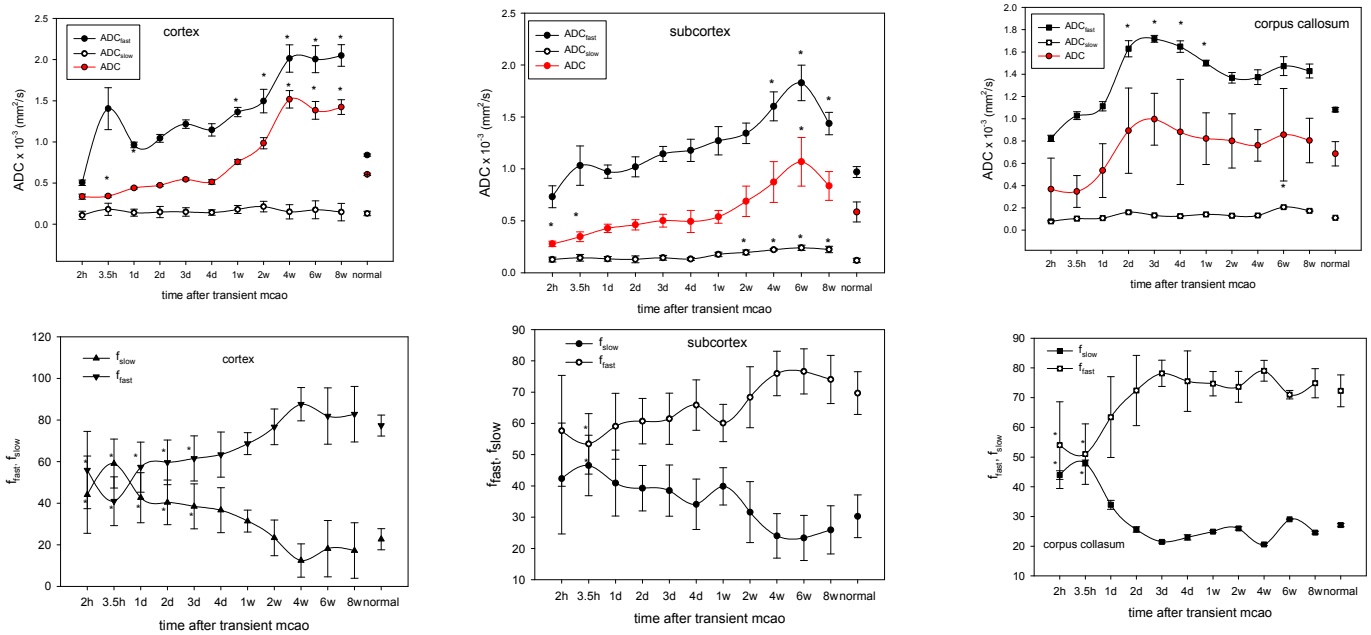

Fig 1. Each point is an average of the absolute values (n = 9) from the ischemic region (cortex, subcortex, and corpus callosum) and the normal presents the average of the healthy controls (n = 9). The evolution of the diffusion mutlicomponent parameters; are presented over the 8 weeks observation period (2 hours – 8 weeks). Time points that are significantly different from the normal are marked (*).