Evaluation of Multi-component Diffusion Coeffcients in Pediatric Gliomas

He Wang[1], Guang Cao[1], Yuhua Li[2], and Xiujie Duan[2]

[1]MR Research China, GE Healthcare, Shanghai, China, [2]Radiology, Xinhua Hospital, Shanghai Jiaotong University, Shanghai, China

Introduction: Maps of mean diffusivity are generated assuming that the relationship between diffusion-related MR signal decay and b-factor is monoexponential. But, in animal and human studies[1,2], it has been shown that the signal decay with b-factor over an extended b-factor range is better modeled using biexponential decay functions as opposed to monoexponential decay functions. Recent experimental studies have demonstrated that there is a fast and a slow apparent diffusion coefficient (ADC) associated with the decay of vivo water signal in human brain when sampled over an extended b-factor range. A biexponential model allows for interpretations based on extra- and intracellular brain water compartmentation[3]. Furthermore, Bennett KM, et al. proposed a stretched-exponential model which can be used to quantify non-Gaussian signals arising from multiple proton pools[4]. In this study, detailed diffusion measurements of pediatric glioma using multiple b-factors ranging up to 5000 s/mm^2 have been made. Biexponential and stretched-exponential parametrization of the diffusion signal decay curves offer new and unique information to characterize gliomas of children. We explored the values of multi-component apparent diffusion coefficients in predicting the WHO classification of gliomas in children.

Materials and Methods: 17 children with brain tumors underwent brain MR examinations at 3.0T. Measurements of the ADC decay curves were made at 12 b-factors from 10 to 4000 s/mm^2 along three orthogonal directions using SE-EPI sequence by axial slice. Due to the combination of long scan time and limited volume coverage associated with the multi-b-factor, multidirectional sampling, 5 slices was chosen from the T2-weighted sag images with the specific goal of enabling the sampling of the tumor. The acquired signal decay curves were fit with two-segment monoexponential (Low B ADC and High B ADC), biexponential (Fast ADC and slow ADC) and stretched-exponential (DDC and Alpha) models. The traditional two b-factor (0, 800 s/mm^2) calculation (standard ADC) was also performed. Then a statistical comparison among these fits was performed. 17 cases of the brain tumors all were gliomas by surgery. Neuropathological grading was done with WHO criteria.

Results: Fig 1 was an example of graphic presentation of our calculated different ADCs. The result is shown in table 1. Low B ADC, high B ADC, fast ADC, slow ADC, DDC and Alpha between high grade and low grade gliomas in children all presented significant differences (P< 0.05). The low grade gliomas were found to have a higher fraction of the fast diffusion ADC component than the high grade gliomas. The fraction of fast ADC between high grade and low grade gliomas didn't present significant differences(P＞0.05). The standard ADC values of the gliomas between high grade and low grade gliomas also presented significant differences (P< 0.05). Table 1 shows that low B ADC, high B ADC, fast ADC, slow ADC and DDC were more significant statistically than the standard ADC. The difference between the slow ADC within Low grade and high grade brain tumors was the most significant statistically.

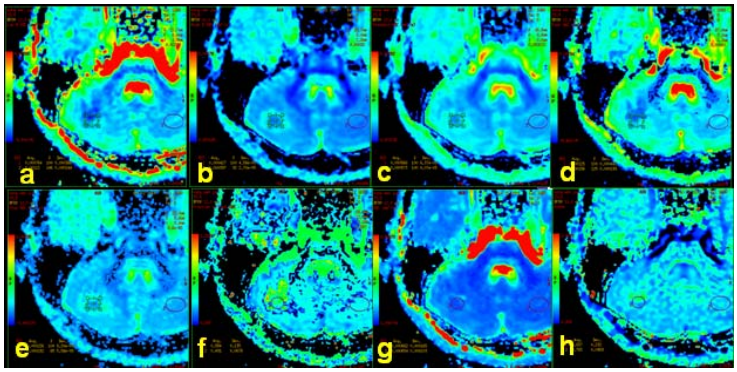

Fig 1 astrocytic tumor(WHO II) in the right frontal and parietal， low B ADC(a)， high B ADC(b), standard ADC(c), fast ADC(d), slow ADC(e), fraction of fast ADC(f), DDC(g) and Alpha(h)

Conclusions: The biexponential and stretched-exponential model can all meet the WHO classification of the pediatric gliomas in the brain more accurately than the standard ADC. Multi-exponential diffusion decay functions are required for diffusion signal decay curves when sampled over an extended b-factor range, providing additional, unique tissue characterization parameters for pediatric gliomas in the brain.

	low grade (I-II) n=7	high grade (III-IV)n=10	T value	P value
Low B ADC（10^{-3}mm^2/s）(b≤200 s/mm^2)	1.58±0.44	0.89±0.39	3.365	0.004
High B ADC（10^{-3}mm^2/s）(b>200 s/mm^2)	0.86±0.28	0.42±0.09	3.938	0.006
Fast ADC（10^{-3}mm^2/s）	2.17±0.52	1.38±0.75	2.384	0.031
Slow ADC（10^{-3}mm^2/s）	0.53±0.23	0.17±0.09	4.559	0.000
fraction of fast ADC（%）	74±16	65±10	1.356	0.195
DDC（10^{-3}mm^2/s）	1.15±0.39	0.58±0.19	3.593	0.007
Alpha	0.98±0.11	0.87±0.11	2.181	0.046
Standard ADC（10^{-3}mm^2/s）(b=0, 800)	1.24±0.44	0.66±0.19	3.238	0.013

Table1 Low B ADC，high B ADC, fast ADC,slow ADC, fraction of fast ADC, DDC ,Alpha and standard ADC of 17 cases of pediatric brain tumors

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