Effect of diffusion time and diffusion gradient strength on the mean diffusivity of DTI in healthy human brain

S. Gao[1], S. Bao[1], H. Ren[2]

[1]Beijing Key Laboratory of Medical Physics and Engineering, Peking University, Beijing, China, People's Republic of, [2]Cangzhou medical college, Cangzhou, China, People's Republic of

Introduction

The effects of diffusion time on apparent diffusion coefficient (ADC) and mean diffusivity (MD) were controversial in previous studies. Some groups (1,2) reported the dependence of measured MD on diffusion time, while the others(3,4) did not found this dependence. Moreover, the effect of the diffusion gradient strength has received little attention. The objective of this study is to evaluate the effect of the diffusion time and diffusion gradient on MD.

Materials and Methods

Images of eight healthy subjects were obtained using a GE 1.5T Signa Twinspeed scanner. A quadrature birdcage coil was used for both excitation and reception. In addition to T1- and T2-weighted imaging, five slices of DTI data encompassing corpus callosum and basal ganglia were acquired using a two-dimensional spin-echo EPI sequence. The scan parameters were as follows: acquisition matrix=128×128, FOV=24cm×24cm, , TR=2240ms, NEX =2, TE ranged from 67.9ms to 96.9ms, FOV=24cm ×24cm.

Two different DTI acquisition schemes were performed on each subject. Diffusion gradient were applied along 13 directions with *b* values ranged from 400 to 2200s/mm^2. In the first scheme, the different *b* values were achieved by varying the diffusion time while keeping the diffusion gradient strength fixed. In the second scheme, the different *b* values were achieved by fixed diffusion time and varying the strength of diffusion gradient. The diffusion tensor and MD was calculated according to the method described by Basser *et al*.(5).

Results

ANOVA revealed that the measured MDs of all ROIs depend not only on the diffusion time but also on applied diffusion gradient strength. As demonstrated in Fig. 1, calculated MD obtained from two representative ROIs decrease significantly as diffusion time or diffusion gradient strength increase. The paired *t* test revealed that MD obtained from the second DTI acquisition scheme significantly bigger than that obtained from the first scheme ($p<0.05$). The MD of cerebrospinal fluid in lateral ventricle decreased with increasing diffusion weighting.

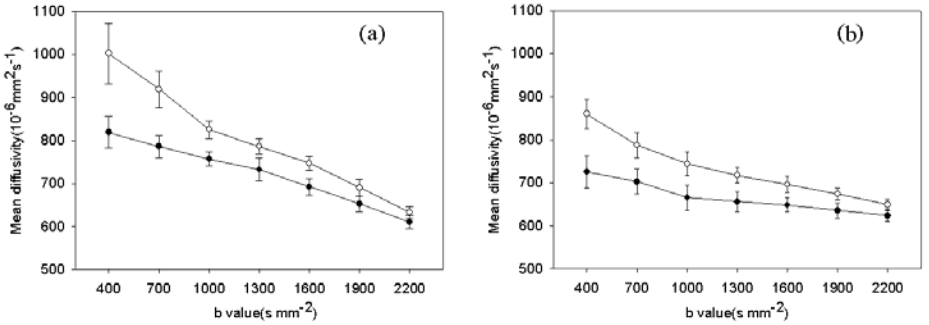

Fig.1. MD obtained from genu of corpus callosum (a) and thalamus (b) plotted as a function of *b* value. The *b* value was achieved by two methods: fixed *G* (black circles) and fixed diffusion time (open circles).

Discussion and conclusions

The results of the current study demonstrated that varying diffusion time had a significant effect on MD. This finding agrees with the result of Gates *et al*.(1) and Horsfield *et al*.(2) The dependence of MD on diffusion time was always explained qualitatively by the interaction between diffusing water molecules and physical restrictions. Diffusion distance cannot increase concomitantly with increased diffusion time due to diffusing molecules will encounter more hindrance. However, Le Bihan *et al*.(3) and Clark *et al*.(4) found MD was diffusion time-independent. In their studies, DTI data were acquired by varying diffusion time, however the strength of diffusion gradient field was not kept constant. Thus, the effect of diffusion time on MD was interfered by the effect of diffusion gradient strength.

The second DTI acquisition scheme of current study was used to investigate the effect of diffusion gradient field strength on MD. Our study demonstrated that MD decreases significantly as diffusion gradient strength increase while the diffusion time was fixed. From the statistical viewpoint, average displacement of diffusing molecules in tissue will keep constant under fixed diffusion time. Thus, this result cannot be explained solely by diffusion in the presence of restrictions. It may be attributed to the limitation of PGSE method. The transverse magnetization decay rate of individual diffusing spin is the cosine of the phase angle. The limitation of PGSE method comes from the periodicity of cosine function. During PGSE experiment, for instance, the phase angle of one spin is α while the phase angle of another spin which diffused a longer distance is $2k\pi+\alpha$ (k is a nonzero integer), PGSE method cannot find the difference between the diffusion distance of this two spins. Therefore diffusion distance of spins of which phase angle are bigger than 2π will be underestimated. In the studies of Le Bihan *et al*.(3) and Clark *et al*.(4), the diffusion time increased, at the same time the diffusion gradient strength decreased synchronously. Effects of the two parameters on MD counteracted each other. Thus, they found MD was diffusion time-independent.

References

1 Gates L. In: Proc 3rd Annual Meeting ISMRM. Nice:ISMRM, 1995,355-355.

2 Horsfield M.A.et al. MRM., 1994,31:637-644.

3 Le Bihan D.et al.NeuroReport, 1993,4:887-890.

4 Clark C.A.MRM, 2001,45:1126-1129.

5 Basser PJ et al., J Magn Reson Ser B 1996; 111:209-219.

Acknowledgment

This work is supported in part by the National Natural Science Foundation (Grant No.10275003).