Three Dimensional Diffusion Weighted MR Imaging and its Biomedical Applications

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A fast three-dimensional diffusion weighted MR imaging (3D-DWI) had been proposed2) and discussed its characteristics2). In the method, the magnetized spins are kept in Steady State Free Precession (SSFP) during the data acquisition. The maximum image intensity (the mean value of some brain tissues) was given at flip angle (FA) of 63 in SSFP and 10 degrees in non-SSFP, respectively. The spin-lattice relaxation time (T2) and diffusion coefficient (D) of biological tissues distributed in three dimensions are enhanced in images reconstructed by this method. For T2 and D enhancement, effective TE (TEm) and MPGs (motion proving gradients) are changed, respectively. From phantom, animal experiments and human studies, the proposed method can be enhanced diffusion coefficients and can apply to clinical diagnosis. This paper describes those experimental results of this imaging method and discusses characteristics and usefulness of the method in the clinical diagnosis.

Methods
Two MPGs with a short duration are applied in every diffusion sequences, and a b-value of diffusion imaging is calculated by the strength, duration and time interval of them. It is able to use rectangular, trapezoid or sinusoidal and others as the MPG waveform. The signal intensity of acquired echo is changing by the b-value, diffusion coefficient is enhanced decreasing of the image intensity depending on the b-value. The proposed 3D-DWI put those MPGs in both side of 180 degree RF pulse and has “90° - MPG - 180° - MPG - 90°” sequence. Changing the b-value enhances the acquired signal relevant to diffusion phenomenon. For the imaging with the shortest TE, the strength of MPG is mostly changes rather than its duration and time interval. Spoiler gradients in three directions can eliminate the horizontal magnetization. A dummy loop in the sequence performs “SSFP” for the vertical magnetization. And then the magnetic moment is imaged under SSFP by refocusing gradients. The signal intensity is increased with appropriate flip angle.

Results and Discussions
By using the 3D-DWI, phantom, rat and human brain images are acquired. As for the acquisition under SSFP, image intensity increases with FA up to 63°. Under SSFP, in addition, free induction decay, spin echo and stimulated echo are also acquired, so higher intensity signal is observed compared with non-SSFP condition. For evaluation of the usefulness of acquisition under SSFP in the method, it is analyzed without MPGs in the sequence. Those reconstructed images are enhanced as the T2 weighted MR imaging. Images were obtained with the TEm of 120msec, effective TR (TRe) of 2500msec, which led to acquisition time of 5.21 minutes for a 256 by 256 by 64 voxels. The maximum image intensity of each ROI was given at FA of 63 in SSFP and 10 degrees in non-SSFP, and the relative intensities in arbitrary scale were 66 for gray matter, 78 for white matter and 130 for CSF in SSFP, and 34, 51 and 7 in non-SSFP, respectively. Figure 1 shows an example of reconstructed image of phantom (water, oil and acetone). A molecule of water and acetone is quickly diffused compared with oil. Enhancement effect of the 3D-DWI compared with the conventional 2D-SE-DWI (spin echo diffusion weighted imaging) defined by the intensity ratio of reconstructed images is almost 0.37.

Conclusions
A new three-dimensional diffusion weighted imaging (3D-DWI) is proposed and discussed. From the results of phantom experiments and brain studies, the 3D diffusion weighted image was obtained. It was possible to keep the magnetic moment in the state of SSFP, the image intensity was found to be increased. This method with a motion correction is applicable to clinical diagnosis. As the proposed sequence as well as conventional sequence is very sensitive to the movement of the biological tissues, the navigator echo or other technique for motion compensation will be needed.

References

Fig.1 A 3D diffusion weighted image (water, oil and acetone, TEe = 30.1msec, TRe = 2000msec, 128 by 128 by 128 voxels)