Volumetric q-space map by Fast 3D DWI.

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Introduction: High b-value diffusion imaging enables us to detect far smaller architectures than the k-space spatial resolution by applying q-space analysis. However, diffusion weighted images are generally acquired by 2D slice with any slice thickness and slice gap, and the partial volume effect makes detection of the q-space signal difficult. We put forward a high resolution isotropic q-space map by 3D diffusion imaging using magnetization prepared fast, spoiled gradient echo sequence.

Methods: All MRI experiments were performed on a 2.0T Biospec 20/30 System with a B-GA20 Gradient System (Bruker, Karlsruhe, Germany) that had a maximum gradient strength of 100mT/m. A 45-mm i.d. saddle coil tuned to 85 MHz for proton resonance was used. 3D DWI sequence parameters were 5000ms/57.57ms (TR/TE), FA of 35º, matrix of 64 ×64×64, FOV of 38.4×38.4×38.4mm and 64 phase-encoding steps per RAGE loop. These MRI diffusion experiments were carried out with different 10 b-values from 0 to 8300s/mm2 MPG duration time (δ) and MPG separation time (Δ) were kept at 24.0ms and 31.2ms, and strength of MPG was incremented from 0 to 92.2mT/m. The total acquisition time was 52min for the whole data sets (64slices×10b-values). To allow for comparison with another diffusion imaging methods, DW SE was performed. This parameters were 5000ms/61ms (TR/TE). The acquisition time was 53min20s in one slice (1slice×10b-values). The temperature in the magnet was maintained at 24.0 ± 0.2 ºC throughout the duration of the experiments. The software construct to 3D q-space analysis and display it was an in-house IDL@ program.

Results and Discussions:

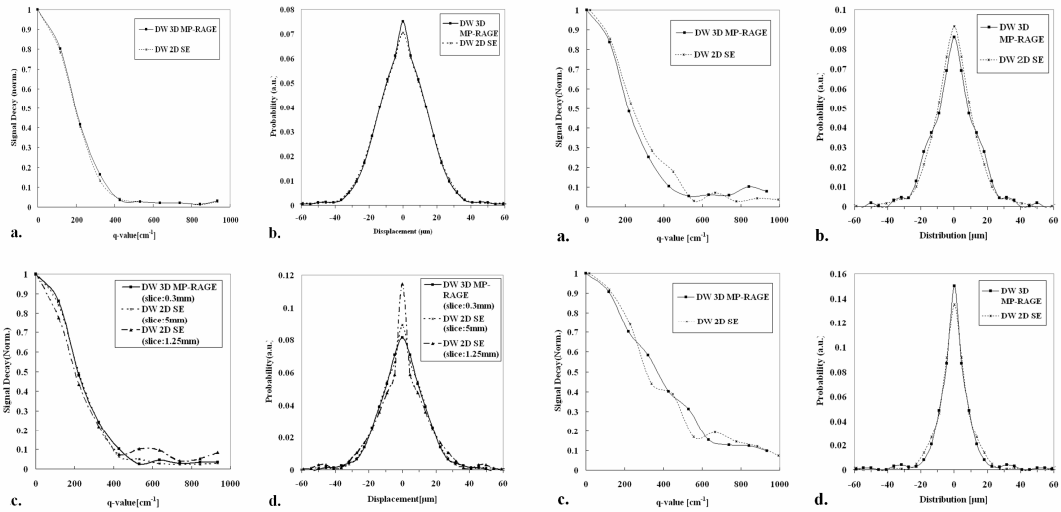

Fig. 1 (a) The changes of diffusion curves in the water phantom by DW 2D SE and 3D DWI. (c) The changes of diffusion curves of the fresh celery (parenchyma) ROI obtained from 3D DWI and DW 2D SE (slice thick:1.25 and 5.0mm).

Fig.. 2 The changes of diffusion curves of the rat brain obtained from CSF (a), CC (c) ROI by 3D DWI and DW 2D SE in the y-direction (⊥:perpendicular to CC.

In fig. 1 (a) DW 2D SE had sufficient signal (SNR = 65.10 with T2WI (b=0)) owing to the thick slice (5.0mm), so the diffusion curve by DW 2D SE must be reliable from the viewpoint of the measurement parameters. The diffusion curve by 3D DWI yielded the changes which decreases in a smooth Gaussian manner. We could confirm that the displacement profile obtained from 3D DWI had mostly the same shape as conventional DW 2D SE.(c) The curve of DW 2D SE (1.25mm) showed more distinct decay than those of the other two curves and the skirt of the decay included a signal wave affected by the noise (SNR = 20.36 with T2WI (b=0)). (c) The changes of diffusion curves of the fresh celery (parenchyma) ROI obtained from 3D DWI and DW 2D SE (slice thick:1.25 and 5.0mm). The curve of DW 2D SE (1.25mm) showed more distinct decay than those of the other two curves and the skirt of the decay included a signal wave affected by the noise (SNR = 20.36 with T2WI (b=0)). (d) The effects of the difference of diffusion curves between DW 2D SE (1.25mm) and others appeared predominantly speculated shape with different peak values ($11.45 \pm 1.21\times10^{-2}$ (2-D (1.25mm)) and $8.91 \pm 0.48\times10^{-2}$ ((2D (5.0mm).

In fig. 2 The curves of 3D DWI obtained from CSF decreases in a smooth Gaussian manner, but that of DW 2D SE had a little divergence (a), and this tendency appeared stronger in CC (c). Generally, the difference of diffusing power among the direction of MPG is small in less restriction areas like CSF. However, the average displacements in the CSF by DW 2D SE were found to be 5.13 ± 0.63μm (∥) and 6.54 ± 0.46μm (⊥). It is considered that any slice thickness (1.25mm) of DW 2-D SE caused a partial volume effect on the ROI measurement and image blurring owing to motion artifacts from the long time measurement in DW 2D SE.

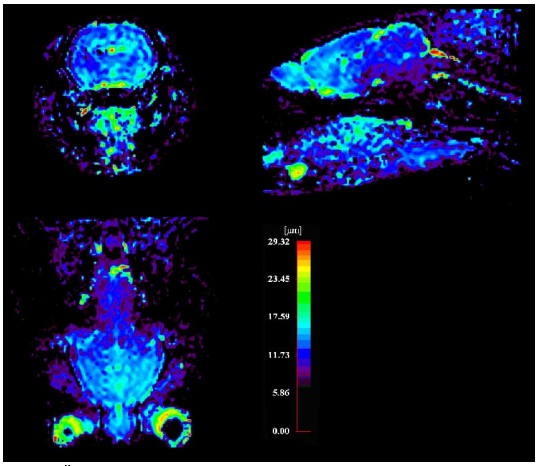

Fig 3 (Right) The 3D average displacement map of the rat brain when MPG was in the x-direction (∥). These maps display the information using a color scaling scheme. We can easily observe minimal changes in continuous by volume manipulation.

Further study is required to expand this method to clinical application and apply higher amplitudes of diffusion gradient. We would then be able to emphasize the diffusion diffraction pattern to clarify the changes of molecular level. This advantage of the volumetric q-space imaging affords some new perspective on the time-based observation of microstructure changes like a molecular imaging.

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