Ex vivo MR diffusion anisotropy measurement for the evaluation of gastric tissue fiber directions using 3D Turbo STEAM sequence

R. Nana[1], N. Metwalli[1], L. Zhou[1], K. A. Heberlein[1], C-K. Eun[2], X. P. Hu[1], C-W. Mun[1,3]

[1]Biomedical Engineering, Emory University/Georgia Institute of Technology, Atlanta, Georgia, United States, [2]Diagnostic Radiology, Inje University, Busan, South, Korea, Republic of, [3]Biomedical Engineering, Inje University, Gimhae, South, Korea, Republic of

Introduction: Various MRI studies such as T1/T2-weighted imaging [1] and single/multi-voxel spectroscopy [2, 3] have been used to evaluate the characteristics of gastric tissues. This study represents another possibility of gastric carcinoma detection by visualizing anisotropic characteristics of proton spins in gastric tissues. Gastric tissue can be divided into three layers: the longitudinal (the most superficial), the circular and the oblique, and muscular fibers are oriented predominantly along these layers. This causes a different direction of anisotropy for the diffusion of water in each gastric tissue layer. Diffusive displacements of water will be largest along the fiber axis and will be partially restricted in the orthogonal directions. Such an anisotropy is illustrated below in a complete diffusion tensor image of a normal human gastric muscle tissue. In order to resolve the fine microstructure of gastric muscular tissue of which thickness is less than 2 mm, a high-resolution 3D Diffusion Tensor Imaging (DTI) sequence is required. We extend the 2D diffusion-weighted single-shot STEAM sequence proposed by Nolte UG *et al.* [4] to a 3D diffusion weighted STEAM sequence for high-spatial resolution imaging of ex-vivo microstructure study.

Materials and Methods: Figure 1 shows the sequence diagram for the 3D DW Turbo STEAM. The technique employs a non-selective double spin echo preparation period in place of the first 90° RF pulse of a conventional high-speed STEAM sequence. The excitation consists of a non-selective $\pi/2$ pulse. The diffusion encoding consists of a double spin-echo with two non-selective π-inversion pulses and four bipolar diffusion gradients. After the last diffusion-encoding gradients the second $\pi/2$ pulse is applied. This is the start of the mixing time TM which ends at the first flash readout pulse. Specific spoiler moments are used to dephase magnetization that do not belong to the coherence pathway of the stimulated echo but nevertheless reach zero phase during the readout interval. The first echo time TE1 is associated with the spin echo of the diffusion preparation and will produce a virtual echo which is not read out, but stored as longitudinal magnetization during the STEAM preparation. The second echo time TE2 describes the time around the TM mixing time. The sequence was implemented on a 3-T Trio MRI (Siemens, Germany) with a hand made small specimen coil (I.D. ϕ = 74 mm, quadrature-birdcage type, Tx/Rx mode). For application to a resected gastric tissue which has been fixed in a polycarbonate plastic tube filled with 10% formalin solution, 3D Turbo STEAM was performed at 0.8 x 0.8 x 0.8 mm^3 resolution using a rectangular 50 x 50 x 32 mm^3 field of view in conjunction with an acquisition matrix of 64 x 64 x 44. An experimentally determined flip angle of 20° that optimized the SNR was used. Diffusion encoding employed b values of 0 and 600 s/mm^{-2}. The corresponding echo time TE1 made as short as possible to minimize T2 relaxation losses and long enough to allow for sufficient diffusion time and suitable set of diffusion gradients. Here TE1 was kept at 60 ms. Complementing the non-DW image, diffusion encoding was accomplished with use of 6 gradients orientations. Data processing software was developed by authors based on VC++ 6.0 (Microsoft USA)

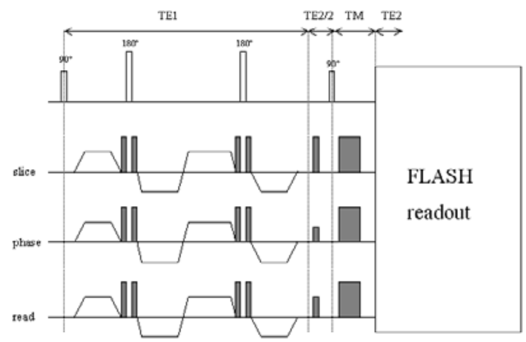

Fig.1. 3D DW Turbo STEAM pulse sequence diagram

Results and Discussion: Figure 2 shows the sagittal view of a non-DW image (A) and corresponding diffusion weighted (B), apparent diffusion coefficient (ADC) map (C), and fractional anisotropy (FA) color map (D) of a cross sectional normal gastric tissue. We can see the mucosa, submucosa, and the muscle layer of the gastric tissue. The muscle layer can be discriminated from other layers in all images. The FA map provides more detail information on the muscle fiber directionalities. This study shows the possibilities of the 3D Turbo STEAM diffusion tensor imaging and can be used as a diagnostic method of gastric cancer disease. In the further study, we would improve the SNR, the resolution and reduce some artifacts such as vibrational motion due to strong gradient pulses.

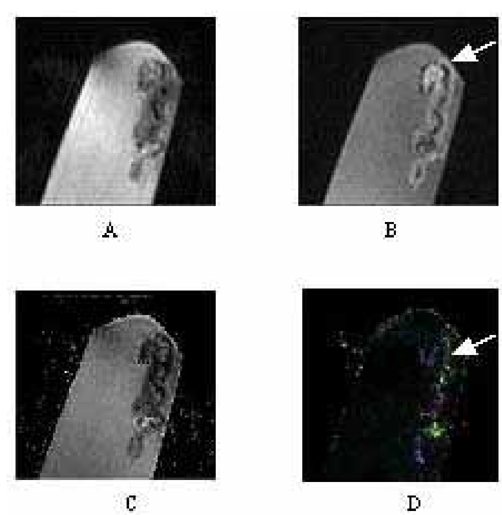

Fig. 2. sagittal view of a gastric tissue.(A): b zero image; (B): DW image; (C): ADC map; (D): FA color map

1. Frank Träber, et al. Magn. Reson. Imag., Vol. 19, pp.537-545, 2004.
2. Auh YH, C.W. Mun, et al. Radiology, Vol. 191: 129–34, 1994.
3. C.W. Mun, J.Y. Cho, K.S. Choi, et al. Magn. Reson. Imag., Vol.22, pp.861-870, 2004
4. Nolte UG et al. Magn Reson Med 2000; 44:731-736.

This work was supported in part by the Inje Research and Scholarship Foundation in 2005.