3D Fast Spin Echo Novel view ordering for variable TE

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Introduction

3D Fast Spin Echo (FSE) with variable flip angle uses low flip angle refocus pulses and long echo trains. T2 weighted 3D images can be acquired with low patient heating (SAR). The effective TE of FSE corresponds to echo train number of k-space center. Sequential view ordering was often used and the k-space center was located at the center of echo trains. To make TE flexible, several view ordering methods were proposed [ref.1] but image quality of sequential (monotonic) view ordering was the best. Novel view ordering method is developed for flexible TE in this paper. Phantom and volunteer were scanned with sequential and novel view orderings. Ringing, blur, signal intensity and contrast were compared.

Principle

Fig. 1 is the new view ordering methods. Ky and Kz mean phase and slice encode in k-space, respectively. Color means the echo train number of FSE. Red and blue mean earlier and later echo train number, respectively. Colored lines mean contour lines of the same echo train number. One black line means the set of k-space data that are acquired in one TR. In conventional sequential ordering (Fig. 1a), the contour lines are straight and the center of k-space is located at the center of echo trains. Type 1 (Fig .1b) is the new view ordering. The contour line has ellipsoidal shape and long to short axis ratio of the ellipsoid is 1.5. The k-space center is located at the beginning 30% part of the echo trains. In type 2 (Fig. 1c), the long to short axis ratio is 3.0 and the k-space center is at 16% of the echo trains. The long to short axis ratio can control the k-space center position along the echo trains.

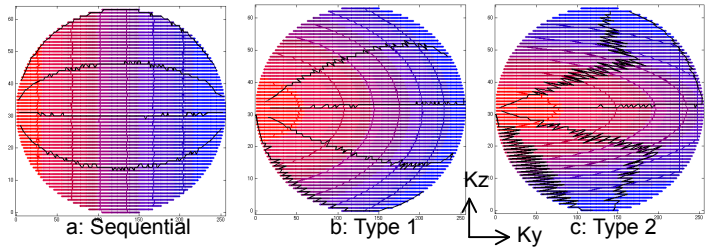

Fig. 1: View ordering along Ky- and Kz-axes

Materials and Methods

Method (1): Cylindrical NiCl2 phantom was scanned with 3DFSE (investigational version of Cube) with different view orderings and ringing and blur were compared.

Method (2): A volunteer was scanned with different view orderings with 3DFSE and 2DFSE under the IRB approval, and written informed consent was obtained from the volunteer. White Matter (WM) and Gray Matter (GM) intensity were measured and images were compared. Flip angle of the refocus pulses was the same in all view orderings and the effective TE was calculated based on [ref. 2]. The effective TE was 109 ms (Sequential), 71 (type 1) and 51 (type 2). 3DFSE protocols were as follows. 1.5T (GE healthcare), 8ch brain coil, sagittal, phase (Y) AP, slice (Z) RL, TR 3000 ms, echo trains 140, FOV 25 cm, matrix 256*256, slice 1mm, 160 slices, CHESS fat sat, fast recovery, parallel imaging * 3, scan time 3:22. 2DFSE protocol was the same as 3DFSE except for the following changes. Effective TE was 110, 68 and 51. Axial, frequency (X) AP, phase (Y) RL, echo trains 15, slice 3mm, 42 slices, Fat Sat off, no parallel imaging, scan time 1:36.

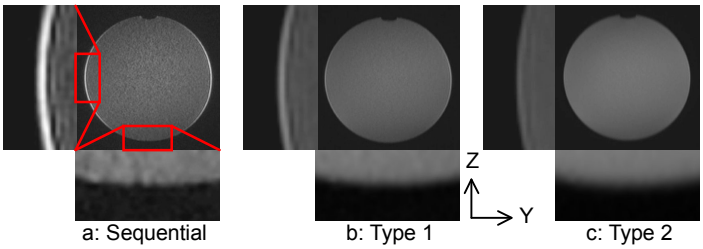

Fig. 2: Phantom image. Ringing on Y-axis and blur on Z-axis.

Results

Result (1): Fig. 2 is the phantom images. New orderings had less ringing on Y-axis. However, they had more blur on Z-axis.

Result (2): In Fig. 3a, signal intensity of volunteer was normalized to GM with effective TE=51. Signal intensity decay along TE was similar between 3DFSE and 2DFSE but 3DFSE has around 10% higher GM/WM ratio in Fig. 3b. Axial reformatted volunteer images are in Fig. 4. Large and Small images are with 3DFSE and 2DFSE, respectively. Window level and width were same between 3DFSE images.

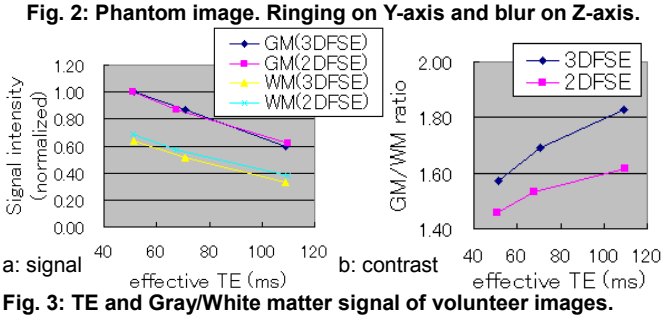

Fig. 3: TE and Gray/White matter signal of volunteer images.

Discussion and Conclusion

On Ky-axis in sequential ordering (Fig. 1a), signal intensity has steeper slope than new view ordering and this results in ringing on Y-axis (Fig.2a). On the other hand, on Kz-axis, new view ordering has low-pass filer like distribution (Fig. 1b,c) and edge on Z-axis has more blur (Fig. 2b,c). Ringing and blur were less severe in volunteer (Fig. 4) than phantom images.

Although the long to short axis ratio was 1.5 (type 1) or 3.0 (type 2) in this work, effective TE can be controlled with arbitrary long to short axis ratio. Whole brain 3DFSE with arbitrary TE, 1mm isometric voxel and 3:22 scan time becomes available with new view ordering.

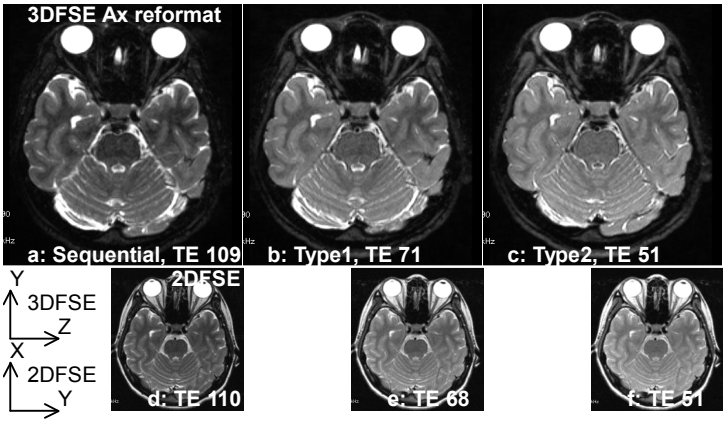

Fig. 4: Volunteer images. 3D/2DFSE with different effective TE

Reference

1. Busse R.F., Proceedings of ISMRM 16 (2008), #1334.
2. Busse R.F. et al., MRM 55:1030-1037, 2006.