Clinical Implementation and Evaluation of High Resolution 3DFSE Whole Brain T2W and FLAIR MR Imaging

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Introduction

High spatial resolution single-slab 3D MR imaging of the whole brain would provide more accurate clinical diagnosis compared to conventional thick slice 2D imaging or multiple-slab 3D imaging. In this study, a single-slab 3D fast spin-echo (FSE) sequence [1, 2] was implemented in a clinical environment and was evaluated using multiple sclerosis (MS) patient images.

Methods

A single-slab 3D FSE sequence similar to that described by Zhao et al [2] was implemented on a 1.5T GE Signa scanner. Dynamic receiver gain approach was used. After each data acquisition, raw data was saved automatically on the host computer and a host program, written in C, was triggered by the pulse sequence to perform 3D image reconstruction. At the end of image reconstruction, correct image header was generated, attached to the reconstructed data, and pushed to the host database. Partial Fourier acquisition was implemented along the second phase encoding direction (from shot to shot). In order to quantitatively evaluate the performance of the partial-Fourier technique, a full k-space data set was acquired as a reference. Partial Fourier encoding data was reconstructed using a 3D version of the previously reported iterative algorithm [3] with different sub-sampling factors. The iteration number was 4.

Twenty clinically definite MS patients were scanned using the conventional 2D SE clinical protocol with either an addition T2-weighted 3DFSE or an additional FLAIR 3DFSE method (10 patients for T2W and 10 patients for FLAIR). The pulse sequence parameters are shown in Table 1.

Table 1 Pulse sequence parameters of 2D and 3D T2W and FLAIR (*: NEX of 0.55; **: NEX of 0.5; ***: NEX of 0.55)

Seq Name	Matrix	pixel size (mm^2)	Sl thick/gap (mm)	TE (ms)	ETL	TR (ms)	TI (ms)	FFT Scan time (min)	PFT Scan time (min)
3DFSE T2W	256x192x160	.94x1.2	1/0	345	192	4300	-	11.5	6.3*
2DSE T2W	256x192x54	.94x1.2	3/0	80	-	3000	-	-	11.5**
3DFSE FLAIR	256x192x80	.94x1.2	2/0	345	192	8000	2450	10.7	5.9***
2DSE FLAIR	256x192x27	.94x1.2	5/1	133	-	8000	2000	4.5	-

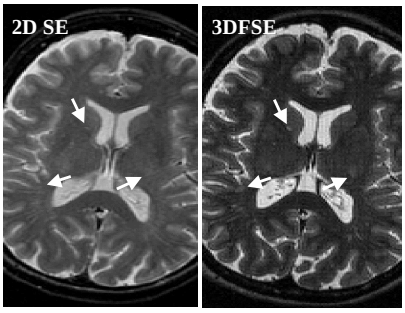

Fig. 1. Lesions and normal tissues that can not be seen or hardly seen on the 2D images are eye-catching on the 3DFSE.

To evaluate the SNR and CNR of the proposed 3DFSE approach and the conventional 2D SE approach, signal intensities of WM, GW, CSF, Lesions and the standard deviations of the background were measured manually using a custom-developed Matlab program. Both 3DFSE and 2DSE data sets were first reformatted and displayed in three orthogonal planes. The locations of ROIs were then carefully aligned across all data sets. The calculated image SNRs and CNRs were normalized by a factor of $1/\left(V_{voxel} \bullet \sqrt{Scan\_time}\right)$ for comparison.

Results

Artifact free T2W and FLAIR 3DFSE images were obtained for all 20 patients. All images could be viewed at any arbitrarily oblique angles with high quality. Image SNR and CNR using 3D FSE and 2D SE sequences with full k-space data are shown in Table 2. Clearly, the normalized SNRs and CNRs using 3DFSE are significantly better than that of 2DSE.

Table 2. Normalized Image SNR and CNR Comparison (W: white matter, G: gray matter, L: lesion, N: noise)

	SNR(3D/2D)				CNR(3D/2D)		
Weight	W/N	G/N	CSF/N	L/N	G-W	C-W	L-W
T2W	0.69±0.13	0.99±0.18	1.44±0.25	1.13±0.25	1.60±0.38	1.96±0.34	1.51±0.54
FLAIR	1.20±0.28	4.14±2.06	1.38/±0.71	1.51±0.34	3.00±1.25	1.18±0.37	1.95±0.66

Figure 1 shows 2D SE and reformatted 3D FSE T2W images of a MS patient brain. While some small lesions and normal tissues can not be seen or hardly seen on the 2D image, they are eye-catching on the 3D FSE image (arrows). This result appeared to be consistent on several patient data sets.

The 3DFSE data was also reconstructed with different sub-sampling factors. The 'overall absolute magnitude differences', relative to the full k-space image, were 4.85, 4.29, 3.81, 2.96 for NEX of .51, .55, .63 and .75 respectively (arbitrary unit). Figure 2 shows images reconstructed using full k-space data, NEX of 0.7, 0.55 and 0.51 respectively. Even though the error was growing with aggressive sub-sampling, image quality appeared to be fairly well even with a NEX of 0.51 (Fig. 2)

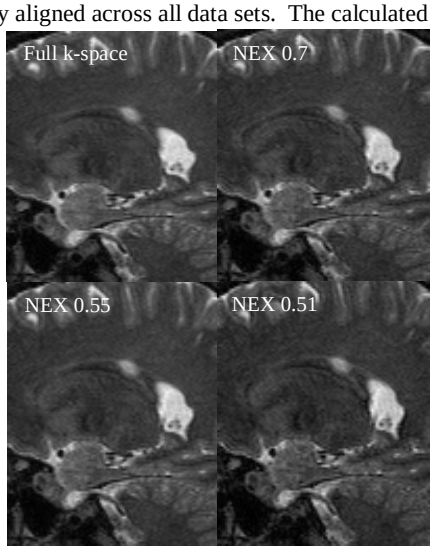

Fig. 2. Images reconstruction with full and partial kspace data (NEX of .7, .55 and 0.5)

Discussion and Conclusions

Due to the use of host online reconstruction, the 3DFSE sequence could be practically used at clinical MR scanners in the same as any product sequence. Normalized image SNR and CNR using the single-slab 3DFSE approach are much higher than using conventional 2D SE approaches for both T2W and FLAIR imaging. Due to the thin slice achieved by the 3D approach, small lesions have much better contrast compared to the 2D approach and thus can be easily detected in their early stage. This is probably due to the partial volume effect. 3DFSE image quality is adequate for clinical diagnosis even with partial Fourier reconstruction. As a result, clinically useful whole head $1mm^3$ T2W and 1x1x2 mm^3 FLAIR images could be acquired only in about 6 minutes. Single-slab 3DFSE is ready for routine clinical study.

References

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