Application of 2D-SENSE to 3D MP-RAGE with Elliptical-Centric Phase-Encoding

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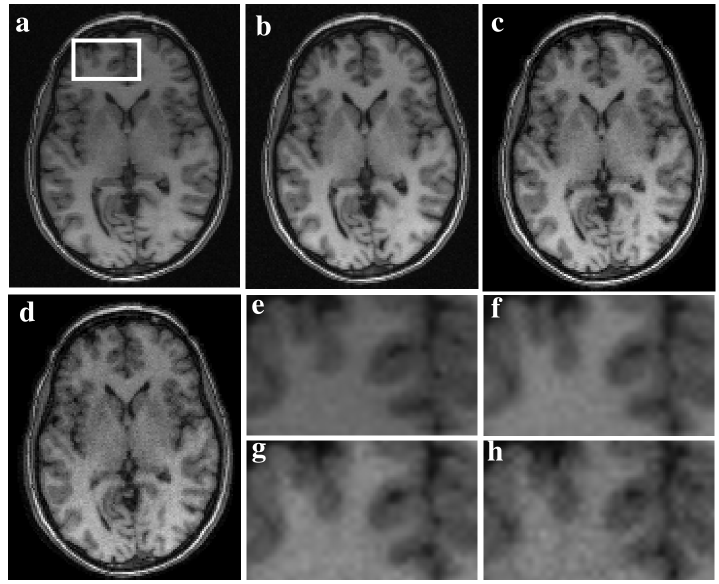
Introduction

3D Magnetic-Prepared RApid Gradient Echo (MP-RAGE) [1] provides excellent diagnostic quality in anatomical scans of the brain and has high T1-contrast between white matter (WM) and gray matter (GM) [2]. A data set is acquired by repeating preparation-acquisition-relaxation cycles until the entire k-space volume is covered. The 3D nature of MP-RAGE lends itself to acceleration via 2D-SENSitivity Encoding (SENSE) [3]. However, many current clinical sequences use a centric-in-k_Z phase-encoding (PE) order whereby the number of cycles is equivalent to the number of k_Y lines. This limits the net acceleration via 2D-SENSE because the total preparation (TI) and relaxation times (TD) are proportional to the number of cycles. 2D-SENSE reduction in the Z-direction would not reduce the number of cycles; hence TI and TD are not reduced. This work applies 2D-SENSE acceleration to 3D MP-RAGE in order to provide reduced acquisition time, better contrast, and less modulation of the MP-RAGE signal in k-space. Thus, it was necessary to de-couple the PE order from the number of cycles while preserving some form of centric encoding. This was done with an elliptical-centric (EC) PE order [4].

Fig. 1. MP-RAGE images from a) full centric-k_Z, b) full EC scan, c) 2X-, d) 4X-SENSE and their respective ROIs (e-h)



Methods and Materials

Similar to the use of square-spiral trajectory for MP-RAGE [5], the EC PE order was segmented into interleaved trajectories that start near the k_Y-k_Z origin. Two normal volunteers were imaged using a 1.5T scanner (GE Medical Systems, 14.0 Excite) and an 8-element head coil. After a localizer scan, 5 scans were acquired with a fast spoiled-gradient MP-RAGE sequence in the sagittal orientation (TR=5.0ms, TE=3.0ms, TI=880ms, TD=500ms, FA=10°, FOV_{xy}=25cm, image size 256×176×144, voxel size 1.0×1.4×1.4mm^3). These included two full k-space scans (centric-k_Z and EC), a halved-resolution calibration scan (EC), and scans for 2X/1D-SENSE (EC) and 4X/2D-SENSE (EC). The number of repetitions per cycle was kept constant in the EC scans, resulting in cycles and scan times shown in Table 1. Scan times were reduced by having more repetitions per cycle in EC, and further by SENSE.

Results

Fig. 1 compares axial slices from the full EC and SENSE reconstructions. The contrast of full-EC is visibly better than centric-k_Z. The image quality of full-EC and 2X SENSE appeared similar. Some noise can be seen in 4X SENSE, but the WM/GM contrast remains similar. WM-GM signal-to-noise ratios (SNR) and contrast-to-noise ratios (CNR) were measured from ten pairs of regions with areas greater than 20mm^2 each. The ratios of GM to CSF intensities (GM/CSF) were also measured to determine how clearly GM could be distinguished from CSF. The average measurements between the two volunteers are shown in Table 1. In both volunteers, SNR and CNR of full-EC scans were superior to centric-k_Z scans. SNR and CNR of 2X SENSE were comparable to that of centric-k_Z scans. Higher accelerations resulted in lower SNR and CNR. SENSE reconstructions had higher GM/CSF than both full scans.

Discussions and Conclusions

SENSE greatly reduces scan time (2.8-5.6× faster) and can achieve comparable or better image quality than current clinical techniques. The reduction in scan time and a radially-symmetric PE order can potentially lead to reduction in motion artifacts. Future work would include clinical assessments of accelerated scans in comparison to full scans.

Table 1. Image quality, number of cycles, and scan time of full scans and SENSE reconstructions

	Full-Centric-k_Z	Full-EC	2X SENSE	4X SENSE
SNR (WM)	27.4	30.4	25.4	17.9
SNR (GM)	15.1	16.6	16.1	10.0
CNR	11.0	13.4	12.1	8.0
GM/CSF	2.9	3.9	4.4	4.4
Cycles	176	100	50	25
Time (s)	372	267	134	66

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