Intensity Inhomogeneity Correction in Human Brain Imaging at 7 Tesla using SPM8

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TARGET AUDIENCE: All researchers who use ultra-high field MRI

PURPOSE: Recent advancement of ultra-high field MRI has enabled the use of 7 Tesla (T) MRI for clinical research, which offers several advantages compared to conventional clinical MRI (3.0 Tesla and below), such as higher signal-to-noise ratio, higher spatial resolution, and enhanced susceptibility effects. However, signal intensity variation or inhomogeneity are remarkable at 7T due to main magnetic field (B0) and RF field (B1) inhomogeneity, susceptibility effects, and inhomogeneous coil sensitivity.[1] Although various techniques have been proposed to correct the signal inhomogeneity,[2] these methods have not been validated at 7T. Therefore, we tested a post-processing technique available with SPM8 (http://www.fil.ion.ucl.ac.uk/spm/), for signal intensity correction of various scan using 7T MRI.

METHODS: Ten healthy volunteers (6 men [mean age, 29.5 years; age range, 24-39 years] and 4 women [mean age, 31.8 years; age range, 28-34 years]) were included in the study. We used a 7 Tesla MRI scanner (Discovery MR950; GE Healthcare, Milwaukee, WI) using quadrature transmit and 32-channel receive head coils. The examination consisted of 5 acquisitions: 2D Spin Echo (2D-SE) (matrix size 1024 and 512), 3D fast SE (3D-FSE), 2D fast spoiled gradient echo (2D-FSPGR) and 3D time-of-flight (3D-TOF) (Table 1). Signal intensity correction was performed using the 'New Segment' method in SPM8. Four different values of full width at half maximum (FWHM) of Gaussian smoothness were used (120, 90, 60, and 30 mm). On each slice at intervals of 8 mm, 8 spherical ROIs with a diameter of 2.5 mm were manually placed in subcortical and deep white matter areas (total 16 ROIs × 8 slices for each subject). We evaluated the signal correction performance using coefficient of variation (CV), defined as the ratio of the standard deviation and the mean signal intensities for all ROIs.[3] A smaller CV represents more uniform signals in the entire white matter. Contrast ratio between the subcortical and deep white matter signals was also calculated. Statistical analyses were performed to see if those CV or contrast ratio values of the original and signal-corrected images (four different FWHM) had significant differences, using the Steel-Dwass nonparametric multiple comparison test following Kruskal-Wallis ($p < 0.05$).

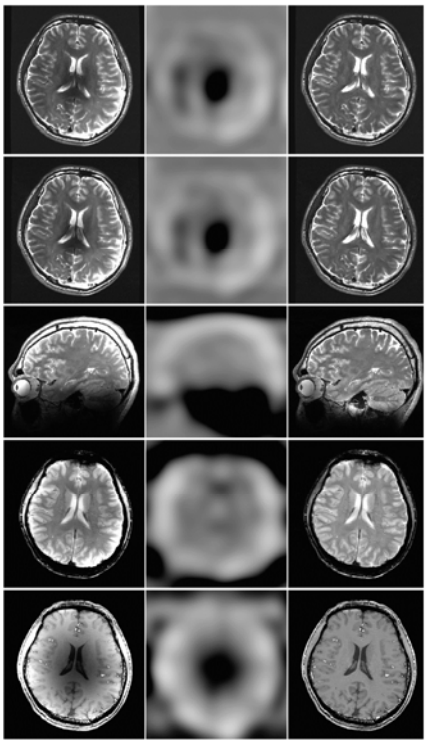

Fig. 1 Original image (left), estimated bias field (middle) and corrected image for FWHM=30mm. The rows correspond to sequences of 2D-SE-1024, 2D-SE-512, 3D-FSE, 2D-FSPGR and 3D-TOF from top to bottom.

RESULTS: The signal intensity of 7 T MR images was successfully corrected using SPM8 (Fig. 1). The CV significantly decreased according to the decrease of FWHM value (Fig. 2). The CV for 2D-SE-1024 and 2D-SE-512 showed the same tendencies of decrease, namely there was no difference in the signal correction between different matrix sizes. In all images, the contrast ratio between the subcortical and deep white matter became close to 1.0 with the decrease in FWHM.

DISCUSSION: In the original images, the signal drop in the center of the brain was remarkable in gradient echo (GRE) sequence (2D-FSPGR and 3D-TOF), possibly due to the signal drop distant to the surface coils. In contrast, the signal drop in the center for SE and FSE images was smaller than GRE sequence; however, some part of the periphery of the brain had signal drop possibly due to B1 inhomogeneity. In both cases, signal inhomogeneity was successfully corrected by SPM8. In addition to the decrease in CV, contrast ratio approached the optimal value (1.0), with the decrease of FWHM. Therefore, the smaller the FWHM value, the higher the efficiency of signal correction. Although the FWHM default value of SPM8 is 60 mm, in 7 T images with markedly inhomogeneous signal, the best FWHM was assumed to be 30 mm, although we did not test smaller values. As we examined only healthy volunteers, further study is needed to evaluate the performance in signal correction by SPM8 in patient groups with various brain disorders such as brain tumors, white matter lesions, etc. In addition, further comparison of the different methods of image non-uniformity correction is needed in the future.

Table 1 MRI parameters used in this study

	TR [ms]	TE [ms]	FA [°]	Voxel size [mm]
2D-SE1024	3000	60	90 and 140	0.25×0.25×4
2D-SE512	3000	60	90 and 140	0.5×0.5×4
3D-FSE	3000	60	variable	0.5×0.5×0.5
2D-FSPGR	800	15	20	0.5×0.5×4
3D-TOF	14	2.9	12	0.5×0.5×0.5

TR: repetition time, TE: echo time, FA: flip angle. Field of view in all images was 256mm.

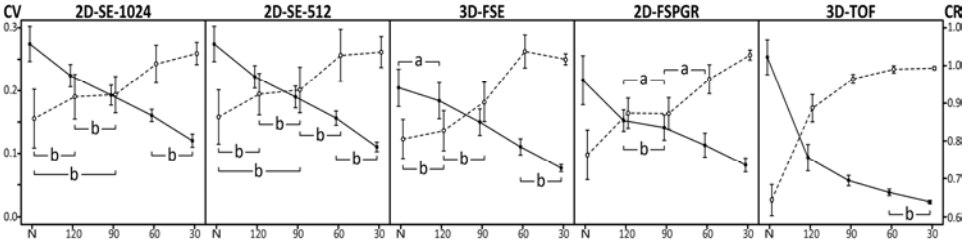

Fig. 2 Mean CV (●) for various FWHM, and contrast ratio (CR, ○) between subcortical and deep white matter. N is original image. a and b indicate FWHM pairs with non-significant difference of Steel-Dwass test in CV and CR, respectively.

REFERENCES: [1] Morelli JN, et al. Radiographics 2011;31:849-866. [2] Belaroussi B, et al. Med Image Anal 2006;10:234-246. [3] Zheng W, et al. NeuroImage 2009;48:73-83.