

T2* myelin water imaging with bmGESEPI for macroscopic field inhomogeneity compensation

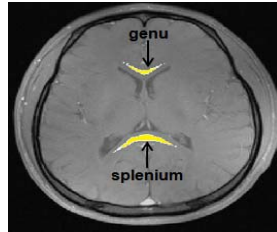
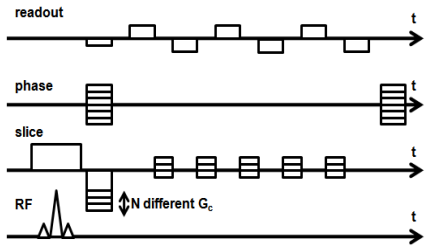
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Introduction Myelin water imaging is a useful tool for studying white matter diseases. So far, a multi-exponential T₂ analysis using multi-echo spin echo sequence has been mostly used for myelin water imaging[1]. Because the trapped water inside myelin sheath has a short T₂ value, these short-T₂ components can be regarded as myelin water. But, using a multi-echo spin echo sequence has some limitations such as high SAR, small coverages and limited first echo time and echo spacing. Therefore, several studies have been conducted using multi-echo gradient echo sequences recently[2,3]. However, T₂* decay curve measured by gradient echo sequence can be easily distorted by macroscopic field inhomogeneity. This is especially true for regions such as the genu of the corpus callosum. When the voxel size in the slice-selection direction is larger than the in-plane direction, the effect of macroscopic field inhomogeneity can be modeled as a linear field gradient in slice-selection direction. In this case, the gradient-echo slice excitation profile imaging(GESEPI)[4] is an effective technique for removing the influences of macroscopic field inhomogeneity by using compensation gradients in slice-selection direction. The blipped multi GESEPI(bmGESEPI) method, a modified version of the GESEPI method, was demonstrated for accurate T₂* measurements with quite less number of scans than the GESEPI method[5]. In this study, the bmGESEPI method was applied for myelin water imaging to remove the effects of macroscopic field inhomogeneity.

Methods *Data acquisition* Figure 1 shows the bmGESEPI pulse sequence used in this study. Blipped gradients(G_c) in the slice-selection direction were added between each echoes to compensate a specific linear field gradient at every echoes. A healthy volunteer(male,29 years old) was scanned on a 3.0T Siemens Tim Trio with following parameters: TR=200ms, flip angle=30°, first TE=2.28ms, echo spacing=1.56ms, 60 echoes(~97.3ms), bandwidth per pixel=888Hz/px, FOV=23x23cm, matrix size=256x256, slice thickness=5mm, N=7 for bmGESEPI(G_c=-1.05%, -0.70%, -0.35%, 0%, 0.35%, 0.70%, 1.05% of the slice rephasing gradient with same duration), total scan time for 7 scans=6min.

Analysis Maximum intensity projection method was used for combining 7 different images. Then the non-negative least squares(NNLS) algorithm was applied to each voxels(the threshold T₂* value of short T₂* component(T₂*_y)=24ms, all 60 echoes were used for fitting). The myelin water fraction(MWF), T₂*_y(averaged short T₂* value, myelin water), T₂*_x(averaged the other T₂* value, the other water), residual norm values were obtained by the results of the NNLS algorithm. Two ROIs, genu and splenium(Figure 2) were manually selected to demonstrate the compensation of macroscopic field inhomogeneity. The same analysis was also conducted using uncompensated image(image at G_c=0%) for comparison.



SPLENIUM				
	MWF (%)	T ₂ * _y (ms)	T ₂ * _x (ms)	Residual Norm(a.u)
Uncompensated	9.8±5.2	5.4±2.9	46.3±2.5	18±4
Compensated	11.9±5.7	7.5±4.0	47.2±3.1	14±2
GENU				
	MWF (%)	T ₂ * _y (ms)	T ₂ * _x (ms)	Residual Norm(a.u)
Uncompensated	67±37	22.5±3.8	26.9±1.8	29±6
Compensated	10.1±5.4	5.42±3.4	46.1±4.6	16±3

Figure 1 The bmGESEPI pulse sequence for compensating the effects of macroscopic field inhomogeneity.

Figure 2 The manually selected ROIs of genu and splenium.

Table 1 The mean and standard deviation values of the MWF, T₂*_y, T₂*_x, residual norm values of the ROIs.

Results Table 1 shows the calculated MWF, T₂*_y, T₂*_x, residual norm values from the voxels in the two ROIs. The results of the genu remarkably changed after the compensating process. The averaged signals illustrate the effect of macroscopic field inhomogeneity in the genu(Figure 3). Without compensation, the signal decay in the genu does not appear like a multi-exponential decay due to macroscopic field inhomogeneity, therefore the fitting error is large leading to wrong fitting result. But with compensation, the signal shows a multi-exponential decay and the residuals decrease. Figure 4 is the results of the entire slice. With compensation, most white matter voxels show small residual norms and short T₂* components.

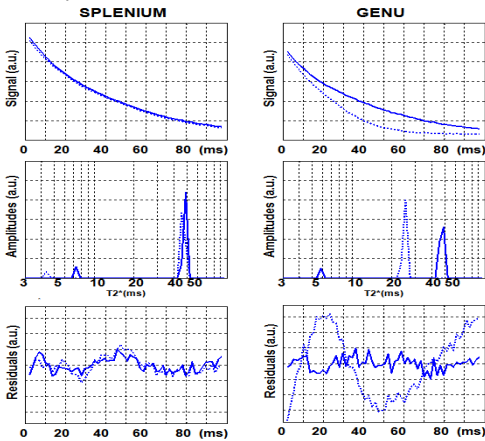


Figure 3 The signal decays, the NNLS fitting results and residual norms of the averaged signals of the ROIs. (dotted line: the uncompensated, solid line: the compensated)

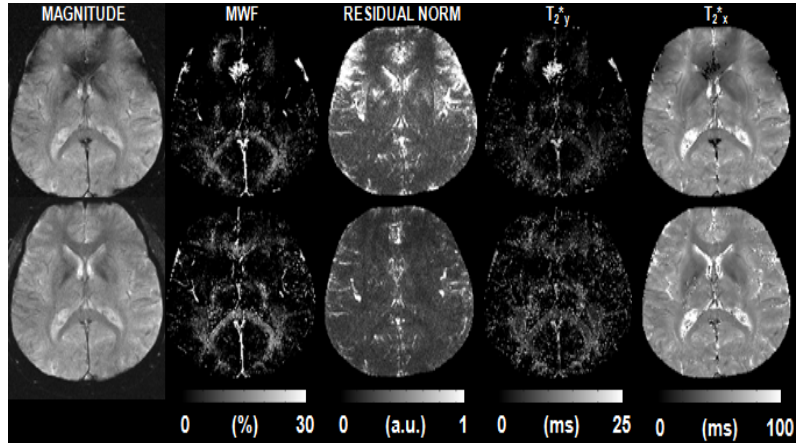


Figure 4 The magnitude(TE=50ms), MWF, residual norm, T₂*_y, T₂*_x images of the uncompensated(upper row) and the compensated(lower row) data.

Conclusion This study demonstrates that the bmGESEPI method improves the accuracy of T₂* myelin water imaging by compensating macroscopic field inhomogeneity. In addition, the MWF values of the genu and the splenium calculated from the compensated image are well agreed with those of the spin-echo method[1].

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References [1] Mackay et al.(1994) MRM,31:673-677 [2] Du et al.(2007) MRM,58:865-870 [3] Hwang et al. (2009) JMRI,30:203-208 [4] Yang et al. (1998) MRM,39:402-409 [5] Truong et al. (2006) MRM,55:1390-1395.