Physiological noise compensation in gradient echo based myelin water imaging

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Target audience: Researchers/Clinicians interested in quantitative myelin imaging or multi-compartment analysis in white matter.

Purpose: Recently, a few studies investigated the signal decay characteristics of multi-echo GRE data in white matter[1,2]. They showed that the signal is composed of two or three components which have different decay rates and frequency offsets. Based on this finding, complex signal models[1,2] were suggested and they generated more reliable myelin water images (MWI)[3]. However, the resulting myelin water fraction (MWF) maps still suffer from artifacts which may originate from physiological sources (e.g. respiration and cardiac). In this work, we explored the contribution of respiration- and cardiac-induced noises in GRE-MWI and proposed an approach to compensate for the noises.

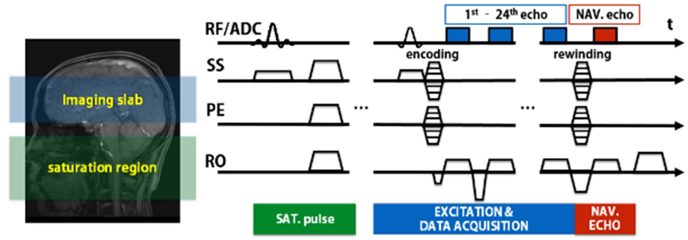

Figure 1. New physiological noise compensation schemes in GRE-MWI

Methods: ***[Cardiac noise]*** Inflow of pulsatile blood induces large artifacts around vessels. To suppress such artifacts, a flow-saturation RF pulse was applied at a lower region (width: 10 cm) of the imaging slab in every TR (Fig. 1). The pulse was placed 20 ms before an excitation pulse. ***[Respiration noise]*** Respiration induces B_0 fluctuation generating phase errors along a PE direction. These errors were corrected by a navigator echo placed at the end of the data acquisition (Fig. 1)[4]. ***[Data acquisition]*** Five volunteers (IRB-approved) were scanned at 3T (Siemens) using a 32 channel coil. For MWI, 3D GRE was acquired with following parameters: TR = 84 ms, # echoes = 25, TE_1 = 1.6 ms, ΔTE = 2.0 ms, flip angle = 60°, BW = 1502 Hz/px, 2 mm isotropic voxel, and 32 slices. To acquire a rapidly decaying myelin water signal, the first TE was minimized and, therefore, no flow compensation gradients were applied. To evaluate the reproducibility of MWI, each subject was scanned four times: Two scans without flow-saturation and the other two scans with flow-saturation. The navigator echo was obtained in all scans. To verify the effects of the respiration compensation, data were reconstructed with and without the navigator correction. Hence, four conditions, FlowSat_Off & B_0Nav_Off, FlowSat_Off & B_0Nav_On, FlowSat_On & B_0Nav_Off, and FlowSat_On & B_0Nav_On were compared. ***[Data processing]*** A complex signal model was fitted to each voxel to estimate MWF. The fitting process was similar to a previous study[2]. Details are described in a separated abstract. The reproducibility was estimated by a correlation coefficient. A paired t-test was used to check the difference between the reproducibility results.

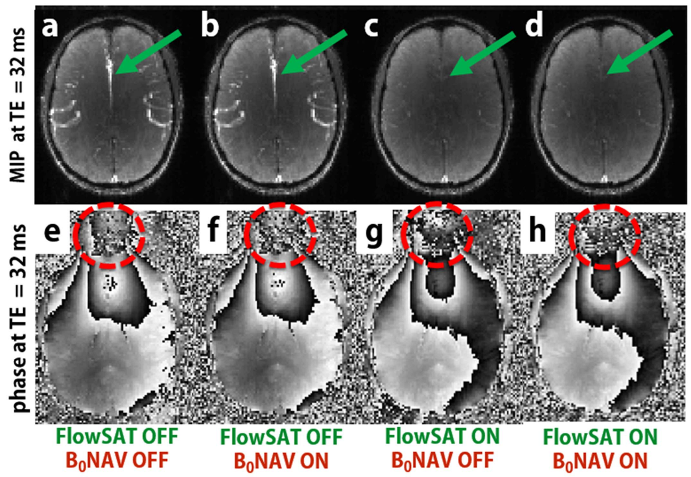

Figure 2. Magnitude (MIP) and phase images for each condition

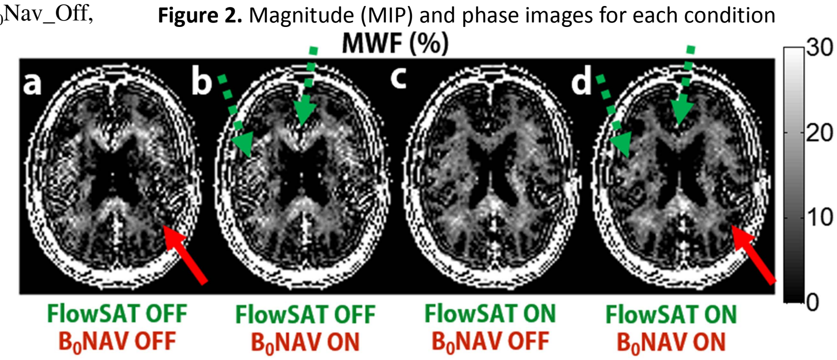

Figure 3. Myelin water fraction (MWF) maps

Results: Figure 2 shows the magnitude (MIP of 9 slices) and phase images (16th echo) for the four conditions. Inflow signals were clearly observed in the magnitude images (arrows in Fig. 2a, b) and were successfully suppressed by applying the saturation pulses (Fig. 2c, d). When the navigator signals were corrected, the phase artifacts (circles in Fig. 2e, g) were reduced (Fig. 2f, h). Figure 3 shows the MWF maps. Large artifacts induced by blood flow signals (green dashed arrows in Fig. 3b) and B_0 fluctuations (solid red arrow in Fig. 3a) were remarkably reduced when both corrections were applied (arrows in Fig. 3d) demonstrating the effectiveness of the proposed methods. The reproducibility results demonstrate that the physiological noise correction significantly improves the reliability of GRE-based MWI (Figures 4).

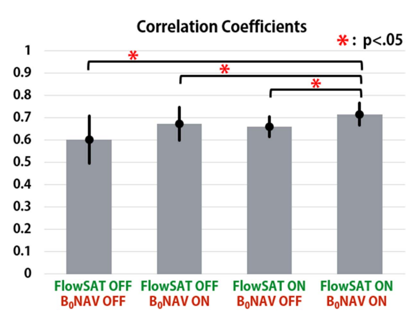

Figure 4. Test-retest results

Discussion & Conclusion: In this study, we demonstrated that physiological noises have significant effects on GRE-MWI, and the proposed corrections significantly improved MWF maps and provided more reproducible GRE-MWI results. When flow saturation RF is applied, it inevitably induces MT effects, which may hamper MWF quantification. The effects can be minimized by using a low power RF pulse and less frequent saturation.

References: 1. Wharton, PNAS 109:18559, 2012. 2. Sati, Neuroimage 77:268, 2013. 3. Nam, ISMRM 2014, p.337. 4. Wen, MRM, in press (DOI 10.1002/mrm.25114).