High contrast-to-noise ratio brain structural images using magnetization preparation and trueFISP acquisition

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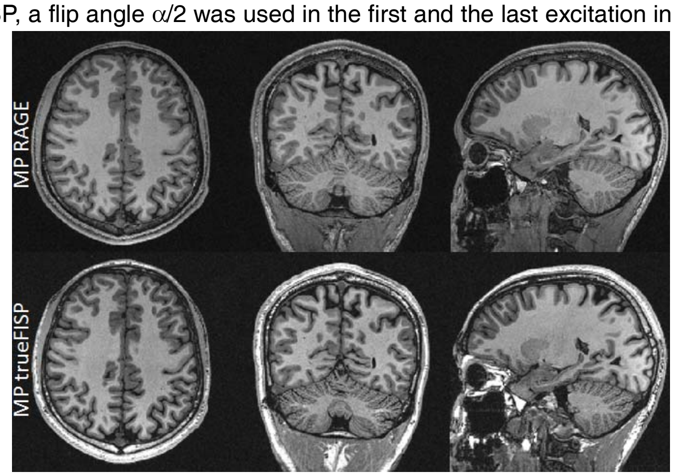
TARGET AUDIENCE Scientists and doctors interested in pulse sequence design and higher contrast-to-noise ratio (CNR) brain structure images for diagnosis and research.

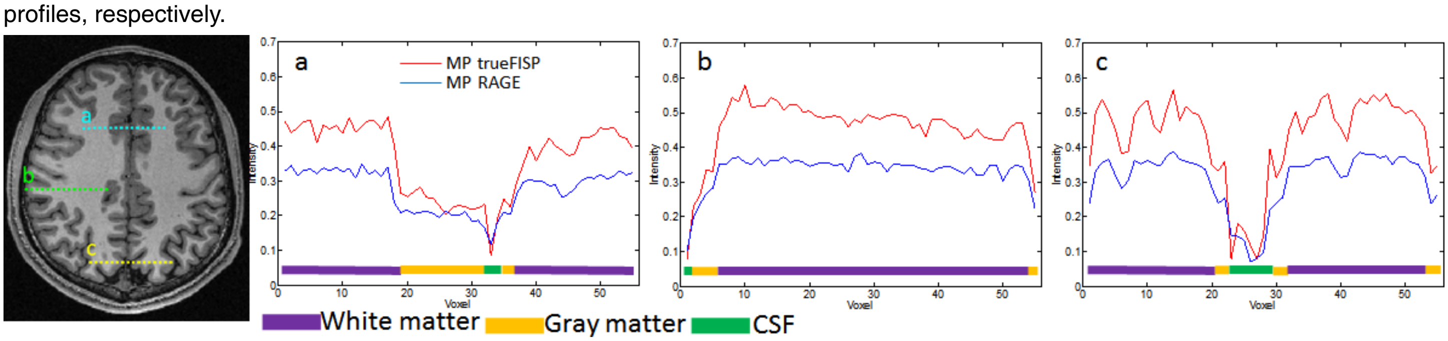
PURPOSE Structural MRI can be a powerful tool in early diagnosis of neurological diseases, such as Alzheimer's disease[1]. It also provides critical anatomical reference to localize brain activity from vascular responses using BOLD fMRI data and estimated neuronal current using MEG/EEG measurements[2]. These applications all require precise segmentation of gray matter from neighboring structures and accurate delineation of gray matter geometry and boundary. The MP RAGE pulse sequence[3] is a prevailing method of providing high contrasts between gray matter, white matter and cerebrospinal fluid (CSF).

Here we hypothesize that these contrasts can be further improved by replacing the FLASH acquisition in MP RAGE by trueFISP. Previously, magnetization prepared trueFISP (MP trueFISP) has been demonstrated in high CNR coronary arteries images[3]. While inversion recovery trueFISP[4,5] sequence can provide accurate brain T_1 quantification, the improvement of gray/white matter contrast by using MP trueFISP has not been studied. We implemented MP trueFISP and measured human brain images at 3T. Our results suggest that, compared with MP RAGE, the contrast between gray and white matter and between gray matter and CSF can be improved by MP trueFISP by 40%-80% at the cost of 37.8% increase in noise, because of using a higher bandwidth per pixel.

METHODS We first optimized the inversion time, TI, and flip angle, α in the MP trueFISP sequence using Bloch equation simulations in order to obtain the highest contrast between gray and white matter based on the published T_1/T_2 [5]. These parameters were further adjusted in experiments. The MP trueFISP sequence had 256 partition encoding steps, each of which started with a hyperbolic tangent adiabatic inversion pulse followed by trueFISP acquisition after a delay of TI. Fat saturation was applied before trueFISP to null fat magnetization to avoid signal oscillation due to off-resonance. In trueFISP, a flip angle $\alpha/2$ was used in the first and the last excitation in order to achieve the exponential recovery steady state at the beginning and efficient magnetization recovery at the end of acquisition, respectively. We used TI = 650 ms, $\alpha = 25^{\circ}$, TR (time between partition encoding steps) = 2530ms, readout bandwidth = 380Hz/pixel, and image matrix = 256 x 256 x 192 with 1mm isotropic resolution. For comparison, a MP RAGE sequence (Siemens) was used with TI = 1100 ms, $\alpha = 7^{\circ}$, TR = 2530 ms, readout bandwidth = 200Hz/pixel, and image matrix = 256 x 256 x 192 with 1mm isotropic resolution. Experiments were performed on a 3T system (Skyra, Siemens).



RESULTS The figure at right shows brain images using MP RAGE and MP trueFISP sequences. Two methods show a similar contrast visually but MP trueFISP has brighter fat and dura. The figure below shows three pixel value profiles in the transverse images. The contrast between gray matter and white matter was improved by 76%, 88% and 44% in three profiles, respectively. The contrast between gray matter and CSF was also found improved by 83%, 49% and 60% in three profiles, respectively.



DISCUSSION MP trueFISP brain images with 40% to 80% improvement in gray/white matter contrast was consistent with Bloch equation simulations. The variation in contrast improvement may be caused by flip angle (B_1) inhomogeneity and magnetic field (B_0) inhomogeneity. We also observed banding artifact near the prefrontal cortex (not shown), which may be suppressed by B_0 shimming coil array[6]. Lastly, noise and mis-alignment between MP RAGE and MP trueFISP slices can also account for this improvement variation.

CONCLUSION A MP trueFISP sequence for brain structural imaging was implemented and tested. Compared with MP RAGE, it improves the contrast from 40 to 80% with 37.8% noise increase due to a wider readout bandwidth. This method can provide high CNR images at 3T if off-resonance can be efficiently managed. MP trueFISP is suitable for low field MRI, where magnetic field inhomogeneity is less serious to use a longer readout in order to further reduce the noise.

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