Expansion of the GESFIDE sequence for simultaneous SWI, T1W imaging and MR Angiography

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TARGET AUDIENCE Researchers and clinicians seeking to evaluate multiple parameters including T1, R2, R2*, R2', MRA and susceptibility weighted imaging in various clinical applications could benefit from this abstract.

PURPOSE Gradient echo sampling of FID and echo (GESFIDE)[1] and its variants[2-3] have been studied to quantify tissue relaxation properties including R_2, R_2* and R_2'. In this abstract, we expand this sequence to also achieve susceptibility weighted imaging (SWI) and T1 weighted imaging. Bipolar echoes are played out to reduce echo spacing. This facilitates multiecho phase unwrapping with CAMPUS[4], which is used to generate improved SWI images. Furthermore, MRA images can be generated at spin echo.

METHODS Experiments were performed on a 3T Siemens Verio scanner (Siemens Healthcare, Erlangen, Germany) equipped with a 32-channel phased array head coil. One normal volunteer participated in the study after providing informed consent. All procedures were approved by the local Institutional Review Board. A total of 7 and 19 gradient echoes were played out before and after the 180 refocusing pulse in the extended GESFIDE sequence[2], with the spin echo at the 15th echo (8th echo after 180). The first echo is at 4.6 ms and the 7th echo is at 21.04 ms. The 8th echo is at 35.82 ms and the spin echo TE is at 55 ms. The last echo is at 85.14 ms. A repetition time (TR) of 250 ms was chosen as a compromise between imaging time and SNR. With nominal T1 and T2* values for white matter (WM), gray matter (GM) and CSF, steady state signal was simulated and is shown in Figure 1. Based on Figure 1, a flip angle of 130° was chosen for the excitation pulse. Other imaging parameters are: FOV = 25.6 cm, bandwidth = 420 Hz/pixel, 32 slices with resolution = 1 × 1 × 2 mm^3. Partial Fourier of 7/8 was used along both phase and partition encoding directions to reduce scan time. The scan takes 22 minutes. CAMPUS phase unwrapping was performed on all echoes before and after the 180 pulse separately. The unwrapped phase images were then used to generate SWI images[4]. The spin echo images can be used to generate MR angiography images with minimum intensity projection after SWI processing utilizing the flow dephasing effects in arteries. Note that the venous signal dephasing is mostly refocused at spin echo due to slow flow. R2, R2* and R2' maps are calculated using echoes after the 180 pulse.

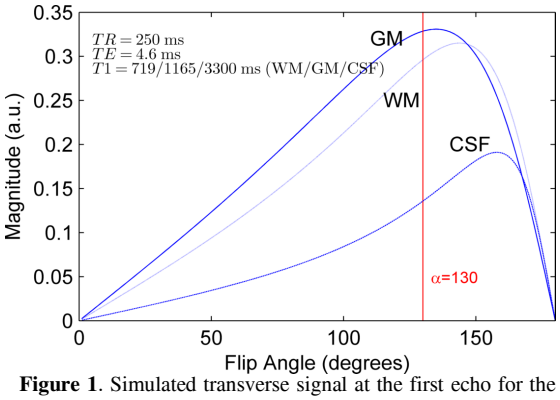

Figure 1. Simulated transverse signal at the first echo for the GESFIDE sequence with nominal T1 and T2* values.

RESULTS AND DISCUSSION Figure 2 shows multiple images generated with the extended GESFIDE sequence. It is seen that the first echo (2a) show great T1 contrast among WM, GM and CSF. With CAMPUS phase unwrapping, the air-tissue interface induced macro-susceptibility was mostly removed and the SWI image (2c) was improved compared to conventional SWI (2d). Good SNR was achieved by averaging multiple echoes at long echo times compared to short echo time (2b). Only arteries were visible in the spin echo image (2e), which was generated with the same slices as the SWI images (2b, 2c and 2d). Furthermore, good R2, R2* and R2' images (2f, 2g and 2h) were also obtained.

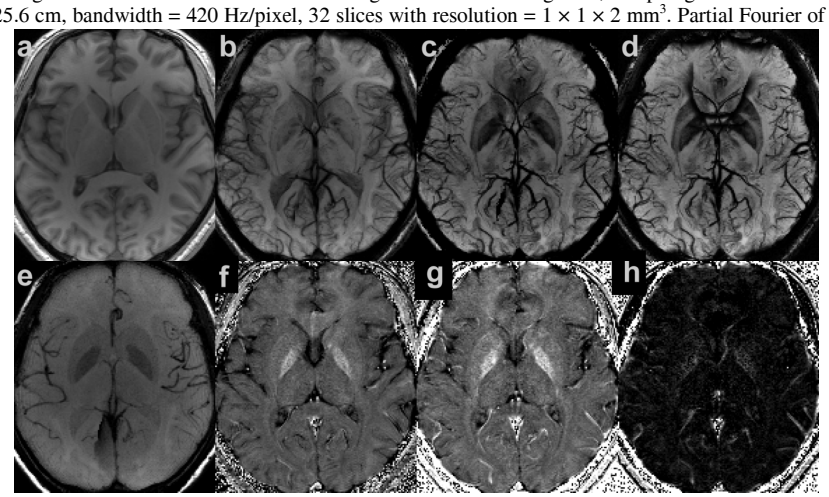

Fig.2. Images generated with the extended GESFIDE sequence. (a) T1W image at first echo; (b) SWI image at TE=21.04ms; (c) SWI image at TE=79.66ms (averaged over 5 echoes from 74.18ms to 85.14ms; (d) Same as (c) but generated with conventional multiecho SWI; (e) MRA at spin echo; (f), (g) and (h): R2, R2* and R2' maps. Note (b), (c), (d) and (e) were generated with minimum intensity projection over 8 slices whose center slice was aligned with the slices shown in (a), (f), (g) and (h).

CONCLUSION We have presented an expansion of the GESFIDE sequence to achieve SWI, MRA as well as T1W images. Our results illustrate the flexibility of the GESFIDE sequence. Although the imaging time is considerably long for clinical applications, parallel imaging and fast k-space sampling strategies such as EPI[3] can potentially mitigate this limitation. The advantage of obtaining multiple tissue parameter images is that all images will be perfectly registered and cross-parameter analysis can be easily and more accurately performed.

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