Self-feeding MUSE: A Method for High Resolution Diffusion Weighted Imaging with Robust Phase Variation Estimation

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TARGET AUDIENCE: Researchers and clinicians interested in high resolution DWI/DTI

PURPOSE: To improve the spatial resolution of diffusion weighted imaging (DWI), many multi-shot acquisition and reconstruction schemes have been proposed [1]. The shot-to-shot phase variations are acquired or estimated to eliminate ghost artifacts. Multiplexed sensitivity-encoding (MUSE) [1] is a multi-shot EPI based DWI method using SENSE [2] for self-navigating. In MUSE, SENSE is used for solving the phase of each excitation, so the reduction factor (R) equals to the number of shot. When many shots are used to decrease the EPI distortion and blurring, the high R will cause inaccurate estimation of phase by SENSE, and hence introduce artifacts in DW images. In this work, self-feeding MUSE is proposed. By using self-feeding [3] mechanism, robustness of phase estimation and MUSE reconstruction can be improved when higher shot number is used.

METHODS:

In MUSE for multi-shot EPI DWI reconstruction, SENSE is firstly performed to get an unaliased image for each excitation, and the phase as navigator information is extracted after smoothing. The accuracy of the phase is critical to the ghost elimination and final image quality, so the number of shot, which equals the SENSE R, is limited due to the noise and artifact amplification of high R.

In self-feeding MUSE, MUSE is firstly performed (step 1). The magnitude of the MUSE reconstruction and the smoothed phase are combined as the prior image for another SENSE reconstruction using the prior information regularized SENSE scheme [4] (step 2): $\vec{x} = \arg\min\{\|A\vec{x} - \vec{y}\|_2 + \lambda^2\|\vec{x} - \overrightarrow{x_0}\|_2\}$ where $\vec{x}$ is the desired image which contains navigation phase, A is the encoding matrix, $\vec{y}$ is the sampled data, $\overrightarrow{x_0}$ is the prior image and λ is the regularization parameter. Then these improved navigation phases are used for the final MUSE reconstruction (step 3). Fig. 1 shows the schematic diagram of self-feeding MUSE.

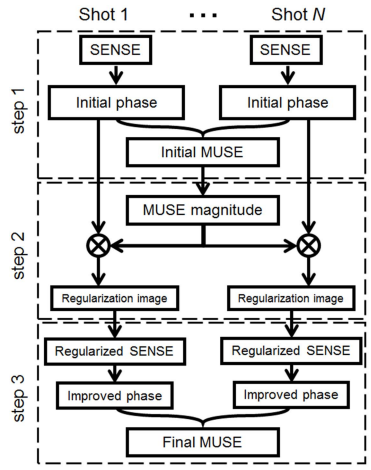

Fig 1. Schematic diagram of self-feeding MUSE.

To demonstrate the advantages of self-feeding MUSE, 6-shot DW EPI data sets with NSA=3 were acquired on a Philips 3T Achieva scanner with an 8-channel head coil. 15 slices were acquired using FOV=220×220mm^2, voxel size=0.89×0.89×4mm^3, 6 diffusion directions with b=800s/mm^2. The initial phase of SENSE reconstruction and improved phase of regularized SENSE were shown in Fig. 2. Reconstructed DW images and color-coded FA maps from original MUSE, self-feeding MUSE and single-shot EPI (2×2. 5 ×4mm^3, SENSE R=2) were compared in Fig. 3.

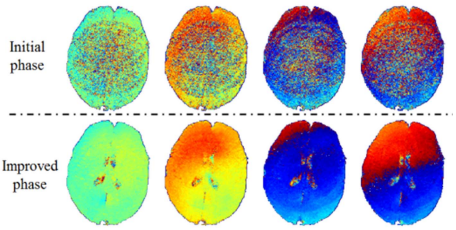

Fig 2. Initial phase of SENSE reconstruction (6-shot DWI, R=6) and improved phase of regularized SENSE reconstruction. 4 shots are shown for illustration.

RESULTS AND DISCUSSION: Since the regularization term will greatly improve the condition of high R (R=6 with 8-ch coil) SENSE, the phase estimation of regularized SENSE has much lower noise/artifact level (Fig. 2), especially at image center where geometry factor is high. The accurate phase estimation will benefit the final MUSE reconstruction. Fig. 3 compares the reconstructed DW images and FA maps of original MUSE, self-feeding MUSE and the single-shot EPI. Compared to original MUSE, self-feeding scheme reduces the ghost artifact (pointed by blue arrow). For color-coded FA map, self-feeding MUSE has more precise directionality estimation than original MUSE, by comparing with single-shot EPI reference (pointed by yellow arrow).

Using the initial MUSE reconstruction results as prior information for regularized SENSE, the phase variations among shots can be calculated more precisely, thus eliminating the ghosts and benefitting the final multi-shot EPI reconstruction.

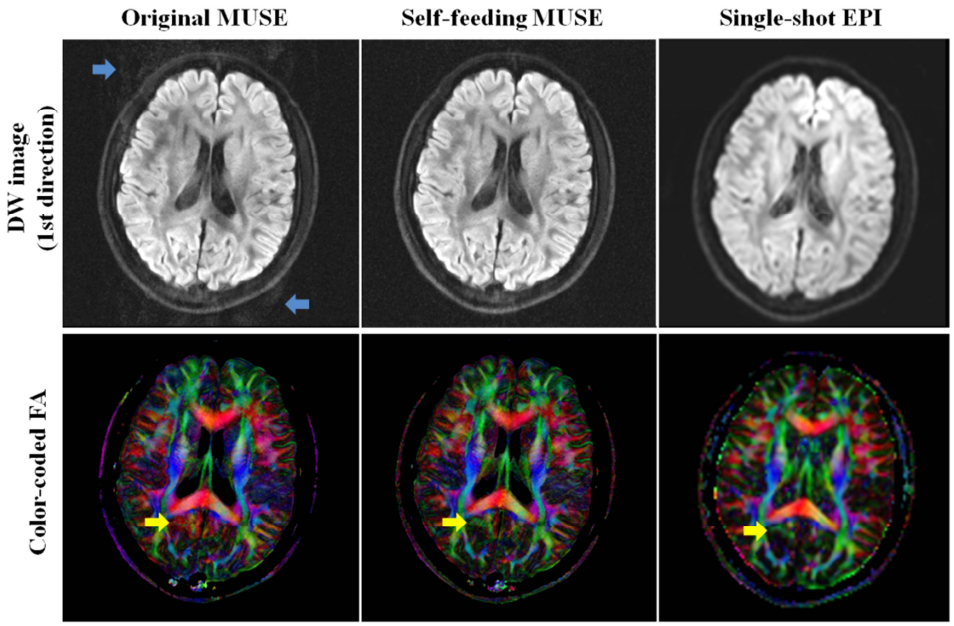

Fig 3. Self-feeding MUSE has less ghost artifacts than original MUSE when shot number=6 (blue arrow) and provides more structure details compared with single-shot results. Self-feeding MUSE provides accurate tensor information (yellow arrow).

CONCLUSION: Self-feeding MUSE provides robustness and accuracy in phase variance estimation and shows its potential for high resolution DWI without need for extra navigator acquisition.

REFERENCES:

[1] Bammer, R., et al. Magn Reson Imaging Clin N Am 17(2009), 175.
[2] Chen, N., et al. NeuroImage 72 (2013): 41.
[3] Pruessmann, K. P., et al. MRM 42.5 (1999): 952.
[4] Huang, F., et al. MRM 64.4 (2010): 1078.
[5] Lin, F. H., et al. MRM 51.3(2004): 559.