# Interleaved 3D multi-slab echo shift sequence for fast T2* weighted imaging

Yajun Ma[1], Wentao Liu[1], Weinan Tang[1], and Jia-Hong Gao[1]
[1]*Center for MRI, Peking University, Beijing, Beijing, China*

**Purpose** To develop a new 3D pulse sequence for fast $T_2$* weighted imaging.

**Introduction** Typical $T_2$* weighted imaging is acquired with gradient recalled-echo (GRE) based sequence (such as FLASH) with long echo time (TE). The total scan time of the 3D FLASH sequence with high resolution is very long. Echo shift technique was proposed for rapidly acquiring MR signals with strong $T_2$* sensitivity.[1] The excited spins are shifted to another later TR by a group of two gradients. Thus, the effective TE is longer than one TR (TE>TR) and the scan time is reduced significantly. However, the SNR of the original echo shift image is decreased due to the effect of the RF pulses during the time between spin excitation and acquisition.[1] In this work, we propose an alternative and novel echo shift strategy, which can simultaneously reduce the scanning time and maintain the high SNR of the image.

**Method** The proposed multi-slab echo shift FLASH (MS-ES-FLASH) sequence is shown in **Fig. 1**. The sequence is based on the full balanced 3D SSFP and additional crush gradients. The areas of the group of crush gradients are -A and 2A, which can shift the echo by one TR. Thus, the effective TE is the summation of the original TE and TR and the effective TR is the double original TR. The steady state of the MS-ES-FLASH with one TR shift is given by following Eq. [1]:

$$M_{\perp}^{'} = M_0 \sin\theta \frac{1-\exp(-TR/T_1)}{1-\cos\theta\exp(-TR/T_1)}\exp(-TE/T_2^{*}) \qquad [1]$$

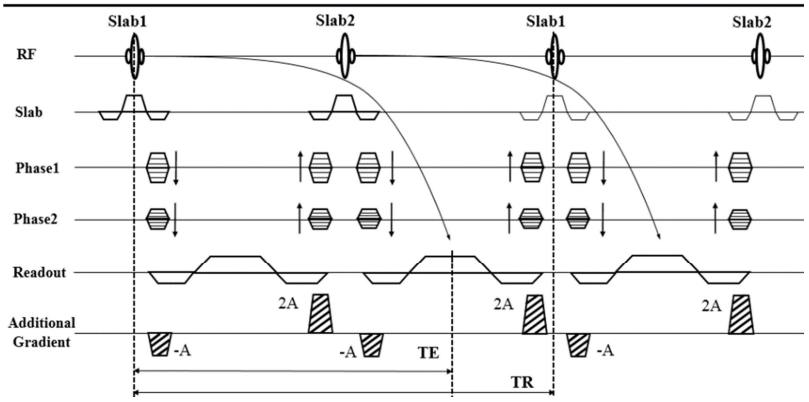


***Figure 1**. The proposed 3D MS-ES-FLASH sequence.*

The steady state is identical to the typical FLASH. Different with the typical echo shift FLASH (ES-FLASH) sequence, the second RF pulse is used to excite another slab. Thus, the second RF pulse doesn't affect the spins which excited by the first RF pulse.

**Experimental results** To validate the advantage of the novel sequence, both phantom and human brain images were acquired on a 1.5T MRI scanner with FLASH and the proposed MS-ES-FLASH sequences. Informed consent was obtained from the volunteer in accordance with the institutional review board policy. The parameters of these two sequences (FOV=220x220x80mm$^3$, TR/TE/θ=50ms/38ms/25$^0$, matrix size=256x256x80, slice oversampling=30%) are identical except the scanning time. The scan time of the MS-ES-FLASH (11min6s) are half compared with typical FLASH (22min11s). The results are shown in **Fig. 2**. The SNR of the phantom images are shown on the top right corners in the corresponding images. **Fig. 3** shows the minimum intensity projection (minIP) images of a 20mm slabs consisting of 20 partitions. The SNR of the images acquired with MS-ES-FLASH is identical to the typical FLASH. Besides, the echo shift technique can attenuate in-flow enhancement of the GRE based sequence (red arrows in Fig. 2). Thus, MS-ES-FLASH leads to enhanced contrast between brain tissue and veins.

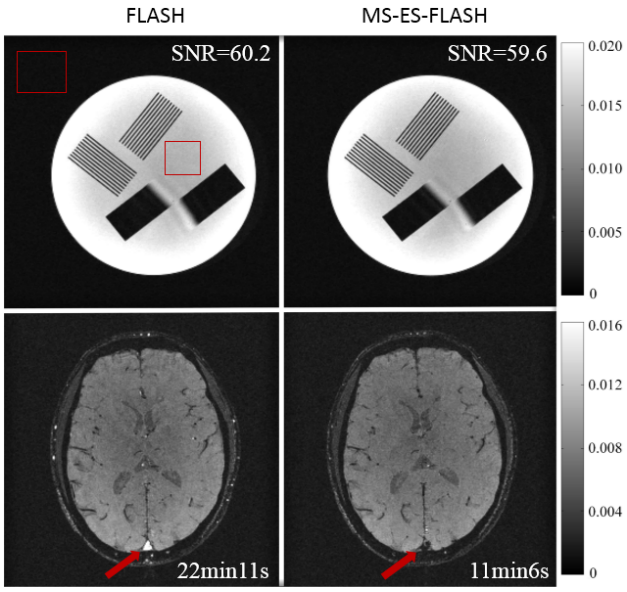


***Figure 2**. Results of FLASH and the proposed MS-ES-FLASH sequences. The SNR of phantom images are shown on the top right corners in the corresponding images and the scan time are shown on the bottom right corner in the corresponding images.*

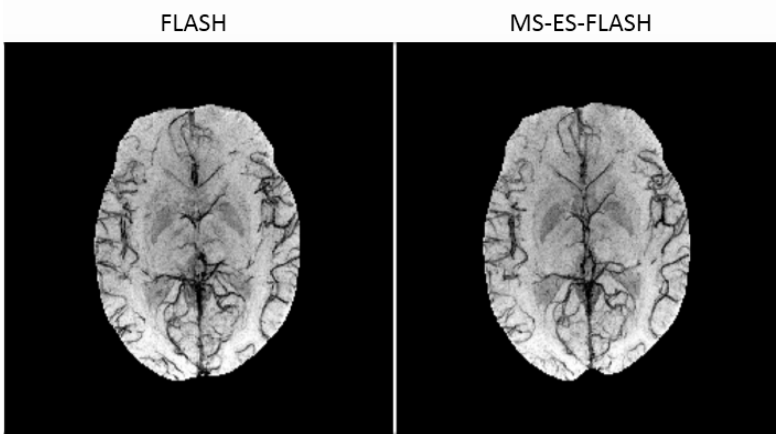


***Figure 3**. SWI results of FLASH and the proposed MS-ES-FLASH.*

**Discussion and conclusion** The proposed multi-slab echo shift technique significantly reduces scanning time without SNR loss. Further, this novel technique has great potential to be utilized in quantitative susceptibility mapping (QSM) or combined with 3D multi-slab EPI and spiral imaging, especially for high field.

**Reference** [1] Liu G., et al., Magn Reson Med 1993;30:68-75.