

## Comparison of short diffusion preparations for 3D black blood imaging.

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**Introduction:** Black-blood MRI can detect carotid plaque burden and thereby assess risk of stroke. Improvements in diffusion preparation for black blood MRI (1, 2) have enabled 3D isotropic vessel wall imaging at 3T (3, 4). Decreasing the MSDE prepulse duration ( $T_{msde}$ ) in 3D motion-sensitized driven equilibrium (MSDE) prepared rapid gradient echo (3D-MERGE) sequence can increase signal-to-noise ratio (SNR)(4). Reducing MSDE duration ( $T_{msde}$ ) while maintaining sufficient first gradient moment ( $m_1$ ) for flow dependent dephasing requires the application of large gradient amplitudes ( $G_{msde}$ ). This can lead to eddy current related signal disturbances. At 3T, effects due to B1 inhomogeneity are also a concern. Therefore for high SNR 3D-MERGE imaging, a MSDE preparation immune to B1 inhomogeneity and eddy current effects should be used in conjunction with short turbo factors (4).

Two alternative MSDE preparations can be potentially used in this context: 1) Reverse bipolar gradients (bpMSDE) with a single  $180^\circ$  pulse [5,6], 2) Twice refocused MSDE preparation (7) with two  $180^\circ$  pulses (iMSDE) (figure 1). bpMSDE has been used in low  $m_1$  applications (6) for reducing B1 inhomogeneity effects. Eddy current effects are also reduced with reverse bipolar gradients when gradient duration is small. While previous 2D MSDE imaging (1, 2) used high  $m_1$  ( $\sim 700$  mT ms<sup>2</sup>/m), 3D-MERGE can achieve good blood suppression with moderate  $m_1$  ( $\sim 100$  mT ms<sup>2</sup>/m) when short turbo factors are used (4). bpMSDE can be used with shorter turbo factors than iMSDE due to reduced SAR demands of the single  $180^\circ$  pulse. Use of moderate  $m_1$  bpMSDE with high gradient amplitudes to reduce  $T_{msde}$  has not been explored for black-blood imaging at 3T. iMSDE has been demonstrated for high  $m_1$  black-blood imaging with reduced B1 and eddy current effects compared to a non-bipolar preparation (7). While iMSDE provides high quality 3D-MERGE imaging (4), its advantages over lower SAR techniques such as bpMSDE are not clear for moderate (or low)  $m_1$  imaging applications such as 3D-MERGE.

**Aims:** 1) To compare iMSDE to bpMSDE for 3D-MERGE imaging in terms of (1) SNR, (2) signal inhomogeneity and (3) immunity to eddy current effects.

**Materials and Methods:** 3D-MERGE was implemented with iMSDE and bpMSDE preparations and spoiled segmented FLASH (T1-TFE) readout. Turbo factors were set to the lowest possible (iMSDE = 35, bpMSDE = 20). Other sequence parameters parameters were similar to previously published parameters (4) (TR: 10ms, TE: 4.8 ms, flip angle  $6^\circ$ , NSA: 1, Bandwidth 134.3 Hz/pixel).  $T_{msde}$  was measured for both sequences using fixed  $G_{msde}$  of 30 mT/m and  $m_1$  of 100, 50 and 25 mT ms<sup>2</sup>/m. A homogenous region of a mineral oil phantom was imaged with both variants with other parameters held identical (table 1). A region-of-interest (ROI) including the full phantom was selected for SNR and homogeneity measurement. SNR was calculated as  $SI/\sigma_{noise}$  (SI: signal intensity,  $\sigma_{noise}$ : standard deviation of noise). Homogeneity was calculated as  $(\sigma_{noise}/\sigma_{noise})$  ( $\sigma$ : signal standard deviation within ROI). By this measure perfect homogeneity is indicated by a value of 1.0. To determine the effects of eddy currents caused by high  $G_{msde}$ , both variants were imaged with at a fixed  $m_1$  of 100 mT ms<sup>2</sup>/m and  $G_{msde}$  of 30, 20 and 10 mT/m. Other parameters were held identical to the previous experiment (table 1). SNR and homogeneity were measured.

**Results:** For a particular  $m_1$ ,  $T_{msde}$  was similar between iMSDE and bpMSDE (table 1). While iMSDE produced homogenous images at all  $m_1$ , bpMSDE images exhibited inhomogeneity at all  $m_1$  with  $G_{msde} = 30$  mT/m (figure 2). bpMSDE homogeneity measures varied upto 2.5 compared to the ideal value of 1.0 while iMSDE homogeneity was closer to 1.0 (table 1). At  $m_1$  below 100 mT ms<sup>2</sup>/m, SNR values of iMSDE and bpMSDE increased only slightly with decreasing  $T_{msde}$ . At all  $m_1$  iMSDE SNR was higher than bpMSDE (table 1). At fixed  $T_{msde}$  reducing  $G_{msde}$  improved SNR of bpMSDE dramatically (table 2) while iMSDE SNR was maintained the same as at  $G_{msde}$  of 30 mT/m. At  $G_{msde}$  of 10 mT/m, SNR and homogeneity of bpMSDE were similar to iMSDE at  $G_{msde}$  of 30 mT/m.

**Discussion:** bpMSDE does not provide an advantage over iMSDE in reducing  $T_{msde}$  if a particular  $m_1$  is desired. Therefore it cannot improve SNR of 3D-MERGE by reducing  $T_{msde}$ . In addition, at a particular  $m_1$  iMSDE provides higher SNR and homogeneity than bpMSDE. The reduced performance of bpMSDE is due to eddy current effects as evidenced by its improvement when  $G_{msde}$  is reduced. By contrast iMSDE SNR and homogeneity are constant over a wide range of  $G_{msde}$  upto the scanner maximum allowed of 30mT/m.

**Conclusion:** iMSDE provides good signal homogeneity and SNR improvement at moderate and low  $m_1$  compared to bpMSDE. 3D-MERGE imaging with moderate  $m_1$  requirements can benefit by use of iMSDE for improved SNR and signal homogeneity. While iMSDE can be used in high, moderate and low  $m_1$  applications, bpMSDE is best suited only for low  $m_1$  applications where eddy current effects can be minimized by a low  $G_{msde}$ .

**References:** [1] Koktzoglou, Radiology 2007, [2] Wang, MRM 2007, [3] Koktzoglou, JMRI, 2007, [4] Balu, MRM, 2010, In Press [5] Nguyen, JMRI, 2008, [6] Fan, MRM, 2010, [7] Wang, JMRI, 2010

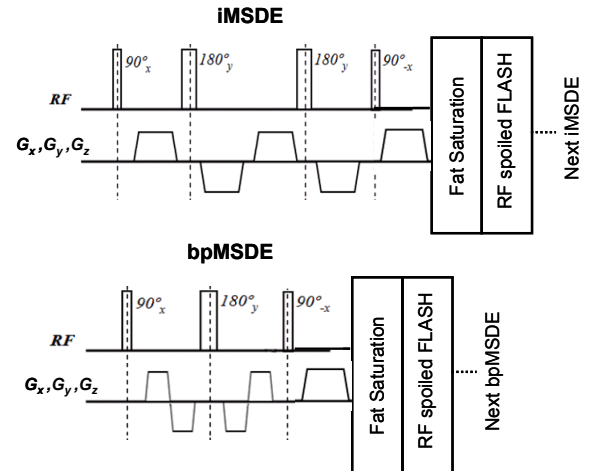


Figure 1: iMSDE and bpMSDE prepared 3D-MERGE.

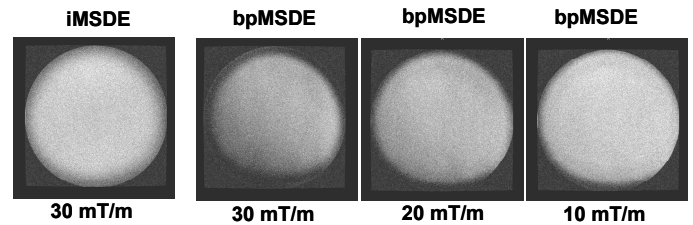


Figure 2: iMSDE provides homogenous signal at  $G_{msde} = 30$  mT/m. bpMSDE signal homogeneity increases with decreasing  $G_{msde}$ . All images presented with same window-level.

	iMSDE			bpMSDE		
$m_1$ (mT.ms <sup>2</sup> /m)	100	50	25	100	50	25
$T_{msde}$ (ms)	9.8	8.5	8.0	8.9	7.4	6.4
SNR	8.01	8.33	8.91	5.46	6.09	6.27
Inhomogeneity	0.83	0.67	0.83	2.50	2.00	2.50
$S_{min}/\sigma_{noise}$	6.83	6.83	6.50	0.0	0.0	0.0
$S_{max}/\sigma_{noise}$	20.83	21.33	21.67	17.17	17.83	18.0

	iMSDE			bpMSDE		
$G_{msde}$ (mT/m)	30	20	10	30	20	10
SNR	8.01	9.0	8.33	5.46	6.33	7.92
Inhomogeneity	0.83	0.67	0.67	2.50	1.50	1.00
$S_{min}/\sigma_{noise}$	6.83	7.50	6.00	0.0	0.33	3.17
$S_{max}/\sigma_{noise}$	20.83	21.17	21.33	17.17	18.17	20.67