Efficient slow-flowing blood suppression technique in atherosclerosis imaging with motion sensitized driven equilibrium (MSDE) TSE sequence at 3T

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Introduction Multi contrast black blood (BB) carotid imaging is important for atherosclerosis diagnosis and accurate plaque component characterization [1, 2]. However, the most popular blood suppression methods, such as inflow pre-saturation band and double inversion recovery (DIR) are still susceptible to plaque mimicking flow artifacts that come from stagnant or slow flow. An alternative technique originally named 'diffusion preparation' sequence in combination with SSFP sequence has recently been proposed as a BB technique for vessel wall imaging [3]. This method, however, actually achieves BB effect by de-phasing rather than diffusion effect. Therefore, we would prefer to avoid the term 'diffusion', but naming it as motion sensitized driven equilibrium (MSDE) sequence. Unlike multi-contrast turbo spin echo (TSE) sequence, SSFP technique has a limited ability to discriminate plaque components. In this report, the MSDE preparation sequence is combined with the TSE sequence and compared to a previously validated multislice DIR sequence [4].

Methods

Sequence Fig. 1 shows the MSDE sequence that is used in this study. The sequence is fully balanced around the 180º pulse. In the presence of flow, the flow suppression efficiency is determined by the de-phasing among moving spins, which is further determined by first and higher order gradient moments. To avoid any phase incoherence of the static spin, the total zeroth gradient moment value is kept to be zero.

Optimization The BB capability of MSDE pre-pulse was first validated on a flow phantom (Phantom by Design, Bothell, WA). It was then optimized for *in vivo* scan to achieve the best blood suppression efficiency and also avoid significant signal drop caused by diffusion and T2 decay. All scans were performed on a 3T scanner (Philips Achieva R1.5.4, Best, Netherlands). A healthy volunteer (32, Male) was scanned after obtaining the informed consent. Oblique carotid artery scans (TR/TE 2000/8ms, FOV 160*160ms, slice thickness 2mm) with various first gradient moment values were performed at the same location. CNR between sternocleido muscle and lumen is used as the optimization goal. The sequence that presents highest CNR was chosen in the following comparison study.

In vivo comparison The MSDE sequence is compared with the previously validated multi-slice DIR sequence [4] with TI of 290ms. Both MSDE and mDIR sequences use exactly the same T2w TSE readout sequence. The readout parameters are: TR/TE 4000/53ms, FOV 160*160mm, matrix 256*256, slice thickness 2mm, NSA 1. To compare the blood suppression efficiency, transversal MR images around carotid bifurcation were acquired on 3 atherosclerotic patients (mean age 59, 2M1F) after obtaining informed consents. After the images are acquired, the following comparisons were conducted.

- SNR of sternocleido muscle (SM), for signal loss comparison
- SNR of carotid artery (CA) lumen, for flow suppression comparison
- SNR of jugular vein (JV) lumen, for slow flow suppression comparison
- CNR between SM and carotid artery lumen on transversal images

Both lumen and outer wall boundaries were delineated for numerical comparison. Paired t-test was used for statistical analysis, an R-value of 0.05 was considered as statistical significant.

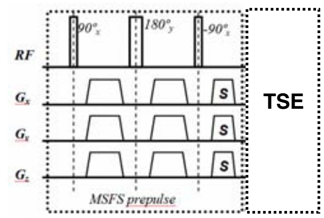

Fig.1 Scheme of MSDE sequence with TSE acquisition

S: spoiler

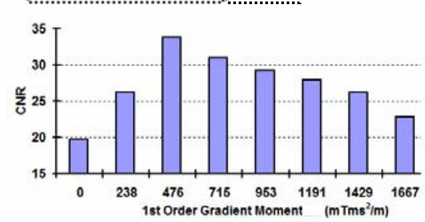

Fig. 2 i*n vivo* CNR optimization for MSDE prepared TSE sequence

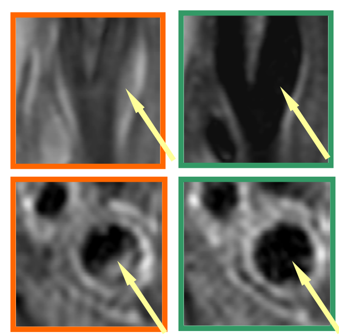

Fig. 3 Comparison of *in vivo* blood suppression efficiency: Left panel: mDIR , Right panel: MSDE sequence.

Table 1 CNR comparison between MSDE and DIR sequences

		Method	Mean	SD	P-value
SNR	SM	MSDE	10.54	1.74	0.63
		mDIR	10.86	1.51	
	CA	MSDE	2.77	0.58	<0.01
		mDIR	4.99	2.29	
	JV	MSDE	2.73	0.62	<0.01
		mDIR	6.55	3.22	
CNR		MSDE	7.78	1.34	0.046
		mDIR	5.88	2.72	

Results

Optimization

The CNR comparison plot is shown in Fig. 2. The optimized MSDE sequence with a first gradient moment of 476mT·ms^2/m produced optimal results providing a trade-off between signal loss in stationary tissues and flow suppression efficiency.

In vivo comparison

MSDE sequence causes a slight SNR loss of about 5% as compared with DIR sequence, possibly caused by both T2 decay and diffusion effect. However, MSDE method has significantly better suppression of the residual blood signal seen from CA and JV lumen. Thus significantly improved overall CNR of carotid wall (P<0.05, Table 1). Images that illustrate the blood suppression efficiency are shown in Fig. 3. It is also noticeable that the MSDE sequence can effectively reduce the plaque mimicking flow artifact, which is seen on mDIR based images (arrow).

Conclusion

Experimentally optimized MSDE technique improves flow suppression, especially in carotid bulb as compared to the DIR technique for both through-plane and in-plane flow. Although MSDE pre-pulse may cause slight SNR drop, this will not significantly change the resulting image quality at 3T.

Reference:

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