Optimisation of Carotid Artery Plaque Imaging using iMSDE Blood Suppression

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Target audience: MR physicists who are interested in carotid vessel wall imaging optimization.

Purpose: Atherosclerotic plaques presenting within carotid arteries are known to be risk factors for subsequent stroke. High resolution black blood MRI of carotid artery vessel wall can visualize high-risk morphologic factors of plaques in vivo and help patient risk stratification [1]. Improved motion-sensitized driven-equilibrium (iMSDE) preparation provides better blood suppression than traditional spatial saturation and double inversion-recovery (DIR) methods [2]. However, iMSDE preparation can cause signal loss, mostly due to eddy current effects and B_1^+ inhomogeneity [3]. We have investigated the CNR and SNR performance of iMSDE prepared MRI using composite RF pulses and sinusoidal gradients.

Methods: Seven healthy volunteers underwent black-blood T1w and T2w MRI of the carotids in a 1.5T MRI system (Discovery MR450, GE Healthcare, Waukesha, WI) using a 4 channel phased-array neck coil (PACC, Machnet BV, Elde, The Netherlands). TR/TE (T1w): 800ms/10ms; TR/TE (T2w):2000ms/50ms; 12cm*12cm FOV,256*192 matrix, 3mm slice thickness, 9 slices to cover the bifurcation; NEX=2; ETL (T1) = 10; ETL (T2) = 16. Quantitative CNR and lumen SNR measurements were performed to compare the performance of DIR with an iMSDE preparation using composite pulses and sinusoidal gradients. The DIR preparation used an inversion time of 691 ms for T1w and 272 ms for T2w, with 1slice per pass for T1w and 4 slices per pass for T2w. The iMSDE preparation time was fixed at 15ms, with a first moment (m_1) of 330 mT*ms^2/m, which was empirically found to be the minimum value sufficient for blood suppression. For T2w imaging, the iMSDE preparation time was included in the effective TE in order to match the DIR FSE acquisition. Composite 180° refocusing and -90° tip-up pulses were investigated to reduce the signal loss due to B_1^+ inhomogeneity. Keeping m_1 identical, we replaced the traditional trapezoid gradients with sinusoidal gradients to reduce eddy current effects. A paired t-test was used to compare two sets of quantitative data and a p-value less than 0.05 was considered as significant.

Results: As shown in Table 1, T1w iMSDE FSE using composite RF pulses has significantly better effective muscle CNR (taking account of scan time) and better blood suppression compared to T1w DIR FSE. T1w iMSDE FSE is three times faster than T1w DIR FSE (3 slices vs. 1 slice per pass). T1w imaging using iMSDE with composite 180° pulses showed the best effective CNR whilst the use of non-composite pulses resulted in the lowest CNR. iMSDE using non-composite pulses also resulted in the lowest lumen SNR but this was due to the poor SNR of the whole image. There was no significant difference among the blood suppression performance using other combinations of composite pulses (CP180, CP180_90 and CP90).

Effective Muscle CNR (mean)	DIR (31.8)	CP180 (40.4)	CP180_90 (38.8)	CP90 (36.5)	NOCP (22.3)
DIR (31.8)	\	P<0.0001	P<0.0001	P<0.0001	P<0.0001
CP180 (40.4)	\	\	P=0.02	P<0.0001	P<0.0001
CP180_90 (38.8)	\	\	\	P<0.0001	P<0.0001
CP90 (36.5)	\	\	\	\	P<0.0001
NOCP (22.3)	\	\	\	\	\

Lumen SNR (mean)	DIR (6.1)	CP180 (4.1)	CP180_90 (4.3)	CP90 (4.2)	NOCP (3.3)
DIR (6.1)	\	P<0.0001	P<0.0001	P<0.0001	P<0.0001
CP180 (4.1)	\	\	P=0.06	P=0.30	P<0.0001
CP180_90 (4.3)	\	\	\	P=0.32	P<0.0001
CP90 (4.2)	\	\	\	\	P<0.0001
NOCP (3.3)	\	\	\	\	\

Table 1. Effective Muscle CNR and lumen SNR measurements for T1w imaging using DIR and iMSDE preparations. CP180: composite 180 pulses only; CP180_90: both composite 180° and composite -90° pulse; CP90: composite -90° pulse only; NOCP: no composite pulses.

With the same m_1, T1w iMSDE (CP180) using sinusoidal gradients had comparable muscle CNR compared with iMSDE (CP180) using trapezoidal gradients (34.1 vs. 35.5, p=0.16), but had significantly higher lumen SNR (4.1 vs. 3.7, p=0.001). T2w iMSDE with either sinusoidal or trapezoidal gradients had comparable CNR compared with T2w DIR (sinusoid: 18.6, trapezoid 18.3 vs. DIR 18.1, p=0.18, 0.44, respectively). T2w iMSDE with trapezoidal gradients had a significantly lower lumen SNR than T2w DIR (4.06 vs. 4.74, p <0.0001), but T2w iMSDE with sinusoidal gradients did not show any differences with T2w DIR (4.67 vs. 4.74, p=0.78). The use of sinusoidal gradients did not have any noticeable effects on overall image quality.

Discussion: We found iMSDE with a relatively small first moment significantly improves the blood suppression compared to traditional DIR methods in carotid vessel wall imaging. The use of composite 180° refocusing pulses demonstrated the best CNR performance, without the need to use a composite -90 flip-up pulse. The use of sinusoidal gradients did not improve the CNR and resulted in an apparent reduction in blood suppression compared to trapezoid gradients with the same m_1. Since the value of m_1 is small in our study, eddy currents did not appear to have an impact on overall image quality. Since we were primarily interested in the effect of composite pulses and sinusoidal gradients and we did not specifically optimize the m_1 value in this study, which may be subject dependent.

Conclusion: iMSDE provides significantly better blood suppression and better/comparable effective CNR in T1w and T2w imaging compared to DIR methods. The use of composite 180° refocusing pulses significantly improves effective CNR performance compared to iMSDE without composite pulses for T1w imaging. In this study the use of sinusoidal gradients resulted in poorer luminal signal suppression.

References:

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