# 2D and 3D multi-contrast black blood carotid vessel wall imaging applying DANTE preparation

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**Target audience:** Radiologists and MR physicists who are interested in black blood carotid vessel wall imaging optimization.

**Purpose:** Blood suppression is essential for black blood vessel wall imaging, and unsuppressed intra-luminal blood leads to plaque mimicking artefacts [1]. Double inversion-recovery (DIR) methods [2] have become the de facto standard for blood suppressed vessel wall imaging. However, this method is sensitive to the rate of flow replenishment which leads to plaque-mimicking artefacts in the presence of slow and/or complex flow that often occur around the carotid bifurcation [3]. Improved motion-sensitized driven-equilibrium (iMSDE) provides better blood suppression than DIR methods [4]. However it induces signal loss and inherent $T_2$ decay which may not be suitable for $T_1$ imaging. 3D variable flip angle FSE has inherent blood suppression but can still demonstrate residual blood flow artefacts in some situations. Delay Alternating with Nutation for Tailored Excitation (DANTE) shows strong blood suppression ability and only induces small $\sqrt{T_1/T_2}$ weighting [5]. However, DANTE has rarely been studied in multi-contrast 2D/3D carotid vessel wall imaging. This study aims to evaluate the efficiency of DANTE blood suppression and SNR performance in 2D $T_1$ and $T_2$ weighted FSE sequences and 3D variable flip angle FSE (CUBE, GE Healthcare) sequence in comparison with DIR and iMSDE preparation.

**Methods: (a) Study population:** Six healthy volunteers underwent black-blood 2D $T_1$w and $T_2$w FSE with DIR, iMSDE and DANTE preparation of the carotids in a 1.5T MRI system (MR450, GE Healthcare, Waukesha, WI) using a 4 channel phased-array neck coil. Another six volunteers underwent 3D isotropic resolution $T_1$w CUBE with iMSDE/DANTE preparation. **(b) Scan protocol:** 2D scan parameters were: TR/TE ($T_1$w): 800ms/10ms; TR/TE ($T_2$w):2500ms/52ms; 14cm*14cm FOV,256*192 matrix, 3mm slice thickness, 4 slices to cover the bifurcation; NEX=2; ETL ($T_1$) = 10; ETL ($T_2$) = 12. A single and multi-slice DIR sequence was prescribed as defined previously [2]. One slice was acquired per TR in the $T_1$-w protocol and four slices were acquired per TR in the $T_2$-w protocol. Optimised first order moments ($m_1$s) (487 $mTms^2/m$ for $T_1$w and 1518 $mTms^2/m$ for $T_2$w) were used for the iMSDE preparation as defined previously [6]. 3D CUBE parameters were: TR/TE: 440ms/10ms;14cm*14cm FOV; 224*224 matrix; 40 coronal slices; 1.2mm slice thickness (interpolated to 0.6mm); ETL 24. A 487 $mTms^2/m$ $m_1$ was used for $T_1$w iMSDE CUBE. DANTE parameters used for both 2D and 3D imaging were adopted from previous publications [7; 8]: DANTE train length: 150; gap between each RF pulse: 1ms; preparation time: 150ms; flip angle of RF pulse: 11°; gradient amplitude: 20 mT/m. **(c) Image and data analysis:** Lumen and adjacent muscle SNR was measured in order to quantify the blood suppression and SNR performance of the different methods. In total, 48 locations are analyzed in both 2D and 3D images. Non-parametric Wilcoxon paired tests were performed to test within group differences in SNR using the different sequences.

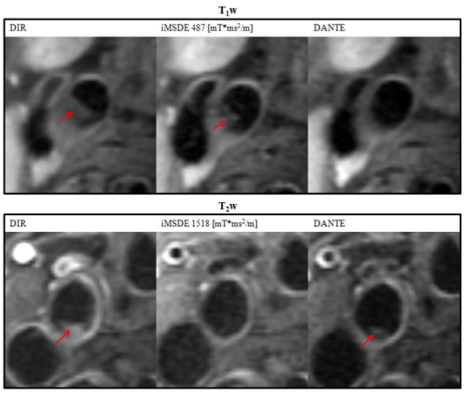


Figure 1 Flow artefacts in 2D DIR $T_1$w and $T_2$w imaging were reduced by iMSDE and DANTE preparations.

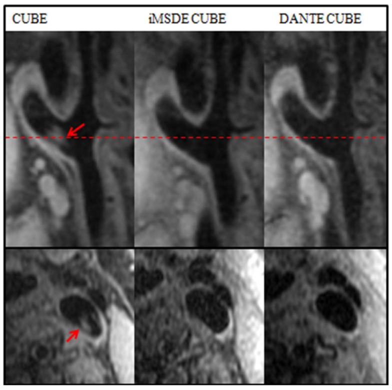


Figure 2 Flow artefacts in reformatted 3D $T_1$w CUBE were removed by iMSDE and DANTE preparation.

| | Muscle CNR median[IQ] | Lumen SNR median[IQ] |
|---|---|---|
| 2D $T_1$w | | |
| DIR | 60.3 [32.6] | 8.8 [3.5] |
| iMSDE | 40.8 [24.2] | 7.3 [3.1] |
| DANTE | 43.6 [22.5] | 5.3 [1.8] |
| 2D $T_2$w | | |
| DIR | 16.8 [12.1] | 6.9 [2.7] |
| iMSDE | 20.7 [11.9] | 4.8 [1.6] |
| DANTE | 13.2 [9.0] | 4.6 [1.2] |
| 3D $T_1$w | | |
| CUBE | 34.1 [12.5] | 5.2 [1.3] |
| iMSDE CUBE | 12.8 [7.5] | 3.8 [0.7] |
| DANTE CUBE | 22.3 [11.0] | 4.2 [0.8] |

Table 1 Muscle and lumen SNR comparison applying different blood suppression modules.

**Result:** In 2D $T_1$w and $T_2$w imaging, both iMSDE and DANTE provided better blood suppression compared to the DIR method ($p<0.001$) (Figure 1 and Table 1). In 2D $T_1$w imaging, the use of iMSDE/DANTE preparation caused significant muscle SNR loss ($p<0.001$). DANTE yielded better blood suppression and muscle SNR than iMSDE ($p<0.001$). In 2D $T_2$w imaging, DANTE preparation reduced the muscle SNR ($p<0.001$) whilst iMSDE increased the muscle SNR ($p<0.001$). DANTE provided comparable blood suppression performance to iMSDE method ($p=0.14$). In 3D $T_1$w CUBE imaging, both iMSDE and DANTE removed the flow artefacts in black blood CUBE images with a lower lumen SNR ($p<0.001$) (Figure 2 and Table 1). DANTE and iMSDE reduced the muscle SNR ($p<0.001$) but DANTE yielded a much higher SNR than iMSDE.

**Discussion:** In this study we have shown both iMSDE and DANTE can improve blood suppression performance than traditional DIR methods in both 2D and 3D multi-contrast imaging of carotid artery wall, albeit at the cost of a reduction in SNR. In $T_1$w imaging, DANTE provided a higher SNR. In $T_2$w imaging, iMSDE provided the highest SNR. This is due to that the inherent $T_2$ decay during iMSDE preparation being included in the effective TE. The effective TE were not exactly matched and iMSDE $T_2$w had a slightly shorter TE (47.2ms) than DIR $T_2$w sequence (52.3ms), resulting a higher muscle SNR. In this study we found the DANTE preparation used in CUBE can removed all the flow artefacts. Due to the inherent black blood effect of CUBE, it is possible that a weaker DANTE module may also be sufficient. Therefore, DANTE CUBE can be further optimized (i.e., reduce flip angle and train length) to achieve better SNR performance.

**Conclusion:** Both DANTE and iMSDE preparation can improve the blood suppression performance in both 2D DIR prepared FSE sequences and 3D black blood CUBE sequences. DANTE is optimal for $T_1$w 2D and 3D imaging for improved SNR. iMSDE is optimal for $T_2$w imaging.

**References:** 1. Balu et al. MRM 57(3):592-599; 2.Yarnykh et al. JMRI 17(4):478-483; 3. Steinman et al. MRM 39(4):635-641; 4. Wang et al. JMRI 31(5): 1256 - 1263; 5. Li et al. MRM 68(5):1423-1438; 6. Zhu JCMR (in revision); 7. Li et al. ISMRM 20:3824; 8. Li. ISMRM British Chapter P64.