Coronary artery wall imaging using DANTE preparation pulses

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Purpose: Double inversion recovery (DIR) has been widely used to null the blood signal in coronary vessel wall studies. However, DIR is more suited to single-slice imaging than to thick-slab imaging [1]. Also, the inversion time is usually more than 600ms for 3T studies, which constrains the imaging window to be late in the heart cycle when acquiring data every heart beat. A novel blood suppression method called DANTE has recently been developed and applied to ungated carotid wall imaging [2]. It is reported to be more time efficient and to generate SNR comparable to DIR. In this study we implemented DANTE preparation with ECG gating for right coronary vessel wall imaging. The performance of DANTE was tested for both 2D multi-slice and 3D scans.

Methods: DANTE preparation consists of a series of non-selective pulses, with phase alternating RF spoiling. The pre-pulses are often placed along the flow direction, with spoiling gradients between pulses. The number of pulses (NP) and the flip angle (FA) were chosen using the numerical simulation equations introduced by [2]. After detection of the R wave and a trigger delay period, DANTE pulses were executed immediately before the imaging module.

Six volunteers were scanned on a Siemens Trio 3T scanner using a 32-channel coil with the following four sequences: 1) 2D breath-hold multi-slice spiral GRE sequence with DANTE preparation. FOV = 280-300mm, three 5mm slices , 5ms spectral–spatial excitation pulse, 14 spiral interleaves with 16ms constant density spiral readout. 2) 3D spiral GRE sequences with DANTE preparation. FOV = 350-400mm, eight 5mm slices, 4-6ms dual-density spiral readout, 18 of 72 interleaves collected within one breath-held. SPIRiT [3] algorithm was later applied to reconstruct missing interleaves. 3) 2D single-slice spiral GRE with DIR, imaging parameters similar to 1). 3) 3D spiral GRE with DIR, imaging parameters similar to 2). In-plane resolution was 0.8-0.9mm for all protocols. For DANTE pre-pulses, NP = 500~600, FA = 7, spacing between pulses = 0.6ms. SNR and CNR of both the left ventricle and the right coronary artery regions were analyzed for all studies.

Results and Discussion: Figure 1 shows right coronary artery images acquired using the four protocols. DANTE pre-pulses give good blood suppression for both 2D and 3D imaging. The blood signal in 3D DIR could not be sufficiently removed, because a large amount of blood in the left ventricle is re-inverted by the second inversion pulse [4]. Local inversion or oblique pulses could alleviate this problem, but DANTE is easier to implement and is more robust to B1 inhomogeneity.

Figure 2 illustrates that for patients who have an early rest period (500-550ms after R wave, 50 heart beats/min), DANTE provides the best combination of blood nulling and wall sharpness (c). In (a), with a short TI = 500ms, the DIR prepared sequence can image during the rest period so that the coronary wall is sharp, but there is still blood remaining in the RCA lumen and left ventricle. In (b), blood suppression is better because a longer TI is used; however, the vessel is blurred due to cardiac motion.

The SNR and CNR analysis is shown in Table 1. The DANTE prepared sequence yielded higher CNR in the RCA region for both the 2D and 3D cases. With 2D DANTE, there is little SNR loss in the myocardium, and the SNR for the RCA is higher because there is less blurring. 3D DIR gives the highest SNR for both left ventricle and RCA wall, but the contrast is too low because of inadequate blood suppression.

Conclusion: We have developed the first cardiac-gated DANTE-prepared black-blood pulse sequences. We tested DANTE preparation for breath-held 2D and 3D spiral scans of the right coronary artery. DANTE pre-pulses were able to successfully suppress blood in the coronary arteries and the left ventricle with little or no SNR loss compared to DIR. DANTE preparation provides for more flexible timing during the heart cycle, allowing for black-blood imaging during the quiescent period.

References: [1] A Scott et al JMRI, 33:77-86, 2011. [2] L. Li et al Magn Reson Med 2012. [3] M Lustig et al Magn Reson Med 2010;64:457–471. [4] RM Botnar, et al Magn Reson Med. 2001;46:848–854.

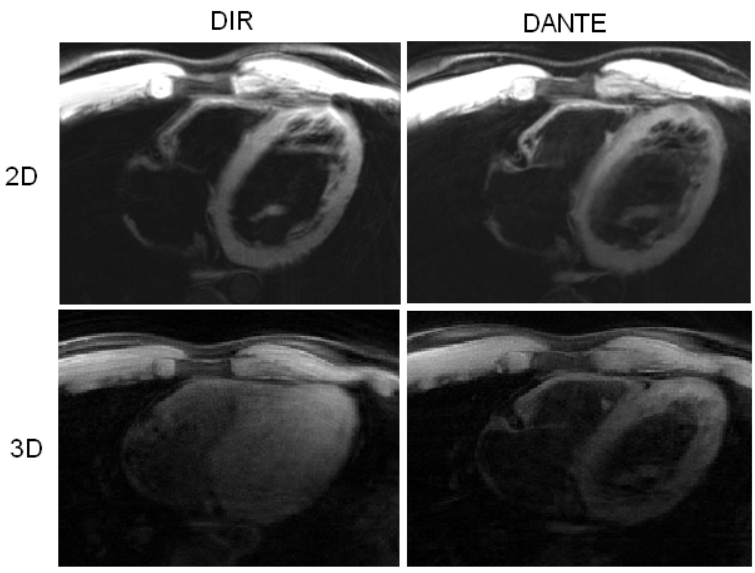

Figure 1 (left). RCA images acquired by 2D and 3D spiral GRE sequence, with DIR and DANTE black blood preparation

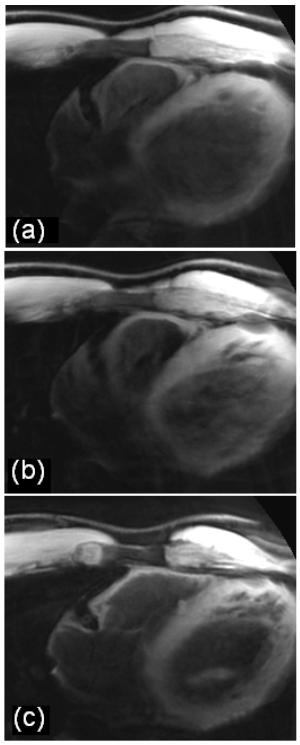

Figure 2 (right). 2D RCA images with (a) DIR, TI = 500ms (b) DIR,TI = 700ms (c) DANTE, TI = 500ms.

Table 1 (bottom) SNR and CNR of 2D and 3D RCA images. Values are mean/STD.

	SNR_myo	CNR_LV	SNR_wall	CNR_RCA
2D DIR	60.21/17.5	38.70/11.1	15.75/7.5	3.59/1.2
2D DANTE	55.72/12.7	35.6/9.15	24.49/13.2	5.46/2.8
3D DIR	65.14/38.0	15.26/5.1	28.86/6.1	3.13/2.44
3D DANTE	47.26/13.1	32.95/14.1	15.73/5.9	4.32/1.5