Free-Breathing 3D Whole Heart Black Blood Imaging with Motion Sensitized Driven Equilibrium

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Introduction: Black blood imaging has been widely used in cardiac MR (CMR). T_1 and T_2 weighted black blood imaging with and without fat saturation are commonly used in the assessment of cardiac masses, myocardium, pericardium and fat in arrhythmogenic right ventricular cardiomyopathy. Double inversion recovery[1] is the most commonly used black blood imaging technique with multi-slice 2D acquisition, which limits spatial resolution, especially in through plane axis. 3D acquisition provides higher SNR and allows improved spatial resolution compared to 2D. However, current cardiac black-blood imaging sequences are not compatible with 3D acquisition and different contrasts. In this study, we sought to investigate the utility of motion sensitized driven equilibrium (MSDE)[2] combined with different imaging sequences (with different contrast property) for blood suppression in volumetric 3D whole heart CMR.

Materials and Methods: After optimization of MSDE parameters in a pilot study of 5 subjects, ECG-triggered (at mid-diastole), free breathing, navigator-echo gated, MSDE-prep whole heart imaging sequence was used to image 7 healthy adult subjects (2 male; 19 to 63 years old, heart rates of 72±18 beats/min) with written consent. In each subject, 8 datasets were acquired: T_1 weighted (T_1w) TSE along the short-axis and axial planes, axial GRE, and short-axis balanced SSFP with and without MSDE preparation covering the entire heart from apex to base. The parameters of the TSE sequence were TE: 10 ms, TR: 1 heart beat, TSE factor: 17-23, BW: 741Hz/pixel, FOV: 300×300×116 mm^3 and spatial resolution: 1.5×1.5×8 mm^3. The short-axis balanced SSFP sequence with a spectrally selective fat suppression had the following parameters: TR/TE/α: 6.3/3.2ms/70°, acquisition window: 103-120ms, BW: 287 Hz/pixel, FOV: 300×300×110 mm^3 and spatial resolution: 1.5×1.5×4 mm^3. The axial spoiled GRE imaging sequence had similar parameters with TR/TE/α: 5.4/2.6ms/20°. The MSDE gradient amplitude in all three directions along the imaging plane was set to 12-17 mT/m. The total MSDE preparation time was ~12 ms. SNR of cardiac structures for each imaging sequence was calculated. A paired t-test was performed to evaluate the significance between SNR of acquisitions with and without MSDE preparation. A two-tailed *P* value <0.05 was considered to indicate significance.

Results and Conclusions: Figs 1 and 2 show example slices from 3D data sets acquired with MSDE. Table 1 summarizes the SNR measurements. MSDE yields significant blood suppression that enables volumetric 3D black-blood assessment of whole heart with 12ms preparation pulse. This blood suppression significantly improves visualization of chamber's walls and papillary muscles. However, MSDE resulted in myocardial signal loss (14%-27%) depending on imaging sequence and orientation and significant artifacts only with SSFP at atrial level.

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References: 1. Edelman et al. Radiology. 1991; 181(3): 655-660 2. Koktzoglou et al. JCMR 2007 9(1): 33-42.

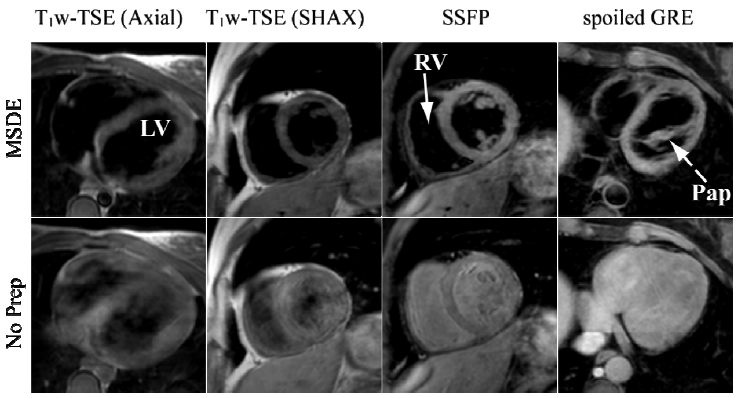

Fig 1: *A single slice from the 3D volume acquired using axial and short axis (SHAX) T_1w-TSE, short axis balanced SSFP, and axial spoiled GRE with and without MSDE preparation. Significant suppression of the blood signal can be seen in all images acquired with MDSE, allowing visualization of the left ventricular (LV) and right ventricular (RV) wall and the papillary (Pap) muscle.*

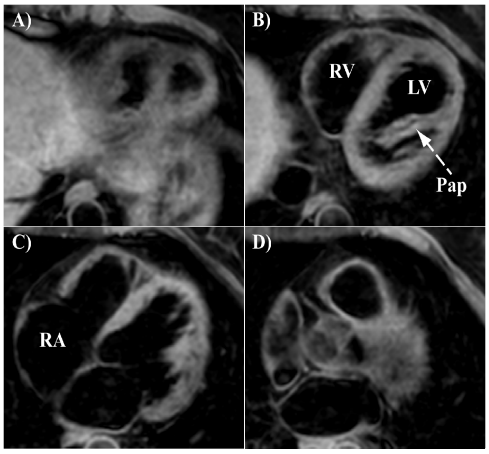

Fig 2: *Four slices from a 3D black blood spoiled GRE sequence with MSDE preparation, demonstrating suppression of the blood pool and improved delineation of the LV myocardium, Pap and the thin RV, RA and LA walls.*

	T_1w-TSE (short-axis)		**T_1w-TSE (axial)**		**SSFP**		**Spoiled GRE**	
	No prep	*MSDE*	*No prep*	*MSDE*	*No prep*	*MSDE*	*No prep*	*MSDE*
LV wall	140±22	102±14*	158±33	126±35	86±35	72±21	111±20	95±20
Septum	134±20	102±14*	154±24	130±21	83±29	77±24	117±19	97±14
LV-blood	87±27	21±5*	96±32	24±7*	104±38	12±5*	110±17	13±3*
RV-blood	93±20	17±3*	94±24	22±7*	95±40	14±4*	118±20	11±1*
RA-blood	89±16	23±9*	98±19	25±10*	NA	NA	135±36	12±2*
LA-blood	96±33	28±12*	90±28	20±5*	NA	NA	128±41	10±2*

Table 1: *mean ± 1 standard deviation of SNR measured over six slices (two apical, two mid and two atrial level) for all the subjects. There is significant blood suppression in chambers with MSDE in all three imaging sequences. RA and LA blood was not measured in balanced SSFP due to an imaging artifact. * indicates P < 0.05*