Free-Breathing Whole-Heart 3D Water-Fat Imaging: Clinical Experience

Valentina Taviani[1], Diego Hernando[1], Christopher J. Francois[1], Scott K. Nagle[1], Mark L. Schiebler[1], Thomas Grist[1,2], Karl K. Vigen[1], Ann Shimakawa[3], and Scott B. Reeder[1,2]

[1]*Radiology, University of Wisconsin, Madison, WI, United States,* [2]*Medical Physics, University of Wisconsin, Madison, WI, United States,* [3]*Global MR Applied Science Laboratory, GE Healthcare, Menlo Park, CA, United States*

Target audience: Clinicians with an interest in cardiac MRI.

Purpose: Chemical-shift-encoded 3D cardiac MR (CMR) can provide robust water-fat-resolved images of the whole heart during free-breathing[1,2]. Clinical applications of whole-heart water-fat imaging include characterization of pericardial disease, cardiac masses and morphological assessment of the aortic root and other complex anatomical features (congenital heart disease (CHD), pulmonary arteries, proximal coronary arteries)[3-5]. Potential advantages over 2D fat-suppressed breath-hold balanced SSFP (steady-state free precession), routinely used to evaluate cardiac morphology, include: 1). more robust fat suppression in the presence of severe field inhomogeneities, providing superior performance near metal; 2). ability to scan patients who are unable to hold their breath; 3). reduction of total imaging time required for cardiac MRI exams by providing high resolution volumetric data sets. In this work we report on our clinical experience with a 3D multi-echo spoiled-gradient-echo pulse sequence with ECG gating and navigators for whole-heart water-fat imaging during free breathing.

Methods: *Patient population:* Fifteen patients (9 males; mean age: 52.6; range: [19, 80]) took part in this IRB-approved study after providing written informed consent.

Imaging protocol: A 3D, RF-spoiled, gradient-echo, chemical-shift-encoded acquisition with ECG gating and navigator echoes (orthogonal 90°-180° localization) was added at the end of an established clinical protocol comprised of pulse sequences for morphology, function and viability imaging (Fig. 1). All source (complex) images were acquired after contrast injection at 3T (GE MR750, Waukesha, WI) with a 32-channel receive-only phased-array surface coil.

Pulse sequence and reconstruction: Four echoes (TE_1=1.3ms; echo spacing=1ms) were acquired in two interleaves with fly-back gradients (Fig. 1a). A T_2 preparation pulse (effective echo time = 48ms) was played out every R-R interval to improve contrast between the blood pool and the myocardium[6]. Imaging parameters included: FOV = 36cm; slice thickness = 3mm; matrix size = 256×160×50; receiver bandwidth = ±142kHz; flip angle=15°; TR=6.3ms. A true spatial resolution of 1.4×2.3×3.0mm^3, interpolated to 1.4x1.4x1.5mm^3, was obtained in 179 R-R intervals using an ARC acceleration factor of 4 and a segmented acquisition scheme with center-out view ordering within each segment (acquisition window duration ≈ 10% R-R interval; scan time ≈ 10 minutes). Separated water-only and fat-only images were obtained using complex fitting and a Graph Cut algorithm for field map estimation[7].

Qualitative analysis: Images were evaluated by two experienced radiologists for overall image quality (0: poor, non diagnostic; 1: fair, some diagnostic information; 2: good, diagnostic; 3: excellent, diagnostic) and level of residual artifacts (0: severe artifacts, non diagnostic; 1: some artifacts, may interfere with diagnostic information; 2: few artifacts, does not interfere with diagnostic information; 3: minimal/no artifacts).

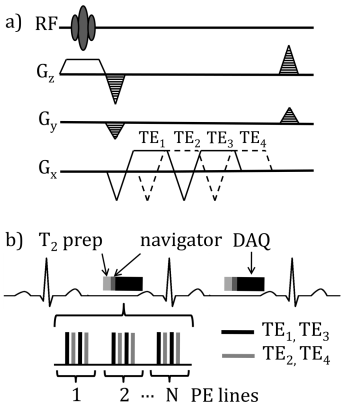

Figure 1: Pulse sequence (multi-echo 3D SPGR with 4 echoes acquired in 2 interleaves) (a) and acquisition scheme (b).

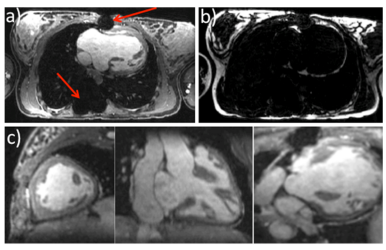

Figure 2: Representative water-only (a, c) and fat-only (b) images acquired in a 19 year old patient with single ventricle and Fontan repair. Note quality of fat suppression in proximity to the sternal wires and spinal hardware (arrows).

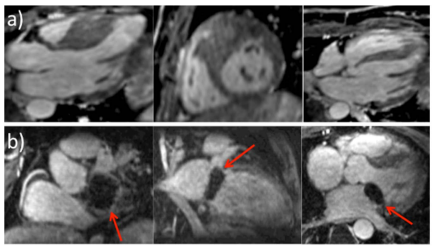

Figure 3: Representative water-only images acquired in a 37 year old patient with hypertrophic cardiomyopathy (a) and a 51 year old patient with a prosthetic mitral valve (b). Note anatomical detail in proximity of prosthesis (arrows).

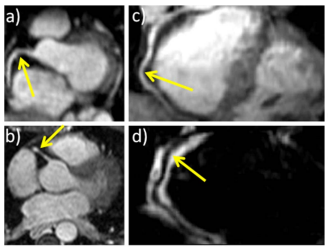

Figure 4: 38 year old evaluated for CAD. Oblique (a-b) and curved (c-d) reformats of the right coronary artery (arrow) performed on water-only (c) and fat-only images (d).

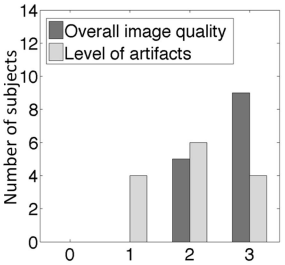

Figure 5: Evaluation of overall image quality and level of residual artifacts (0: worst case; 3: best case).

Results and discussion: Indications for CMR included: CHD, CAD (coronary artery disease), myocardial infiltrative disease, hypertrophic cardiomyopathy and suspected sarcoidosis. Diagnostic images were successfully acquired in all patients. Good fat suppression was observed in all cases (Fig. 2-4). Excellent fat suppression in proximity of metallic implants was also observed (Fig. 2,3). This improved visualization of small pericardial vessels and other complex anatomical features surrounded by fat (Fig. 4). Overall image quality was graded as either good or excellent in all cases (Fig. 5). Significant artifacts occurred in 4 out of 15 cases. The most common artifacts were residual motion artifacts due to very irregular heart rate and/or respiration (2/4) and signal drop-out in proximity of the lateral wall of the left ventricle (LV) due to B_1 shading (2/4).

Conclusion: Chemical-shift-encoded 3D cardiac imaging provides high-resolution water-fat-resolved images of the entire heart in a single free breathing acquisition. This allows evaluation of complex morphological features in patients unable to hold their breath with additional information contained in the fat-only image and the potential for simultaneous R_2* mapping of the myocardium.

References: [1] Taviani V. et al. ISMRM 2012; p. 1226; [2] Bornert P. et al. ISMRM 2012; p. 316; p. 2775; [3] Reeder S.B. et al. MRM 2005; 54(3): 748; [4] Vigen K.K. et al. ISMRM 2009; [5] Kellman P. et al. MRM 2009; 61(1): 215; [6] Brittain J.H. MRM 1995; 33(5): 689; [7] Hernando D. MRM 2010; 63:79.