3D Free-breathing, CINE Magnetization Transfer Imaging for assessment of Whole-heart function and Great Vessels

Eric Schrauben[1], Christopher François[2], Oliver Wieben[1,2], and Kevin Johnson[1]

[1]*Medical Physics, University of Wisconsin - Madison, Madison, Wisconsin, United States,* [2]*Radiology, University of Wisconsin - Madison, Madison, Wisconsin, United States*

TARGET AUDIENCE: Scientists and clinicians interested in 3D evaluation of cardiac function and vasculature.

PURPOSE CINE 2D balanced steady state free precession (bSSFP) provides high blood to myocardium contrast but requires multiple breath-holds for whole-heart coverage and can be compromised by slice-misregistration resulting in overestimation of functional parameters[1]. Furthermore, multi-slice acquisitions are not well suited for multiplanar reformatting, e.g. to create long axis views from a short axis acquisition. While some progress has been made to allow for single-breath-hold 3D bSSFP, these sequences provide reduced contrast and compromise spatial resolution as well as coverage for feasible breath-hold times[2]. In this work, we investigate the alternative use of a novel magnetization-prepared, free-breathing 3D cardiac CINE sequence utilizing highly accelerated sampling. Specifically, we develop a magnetization transfer prepared (MT-prep) 3D radial acquisition with a time domain compressed sensing reconstruction. This approach provides large volume coverage with isotropic spatial resolution, optimal for reformatting in any desired cardiac view.

METHODS: bSSFP provides inherently high blood signal, however a substantial reduction in contrast is observed with 3D sequences[2] from reduced inflow signal. T2-preparation (T2-prep) provides a means to boost contrast, particularly in coronary angiography[3]. However current techniques, requiring spin precession in the transverse plane, are highly sensitive to imperfect refocusing and off resonance induced by motion. A strong MT effect exists in the myocardium due to high macromolecular content and holds potential to provide high blood to myocardium contrast[4]. Unlike T2-prep, MT-prep requires no time in the transverse plane and is subsequently insensitive to artefacts; however, its direct use for cardiac imaging is relatively poorly developed.

Two healthy volunteers were imaged after IRB approval on a clinical 1.5T system (MR450W, *GE*, WI, USA) with standard breath-hold 2D multislice bSSFP and magnetization prepared 3D radial sequences. 3D sequences were acquired after the administration of 0.015 mmol/kg Gadobenate dimeglumine. An undersampled radial trajectory[5] was used to cover the entire heart with both T2-prep SSFP and MT-prep SPGR. MT-prep 3D radial sampling consisted of a high power, highly frequency selective MT-prep followed by a short train of SPGR readouts (parameters: FOV = 64 x 32 x 32 cm, 2.0 mm acquired isotropic spatial resolution, dual echo: TR/TE1/TE2 = 5.6/1.3/3.3 ms, free-breathing, scan time = 8:20 min, α = 4°, 39,000 projections, 10 projections per preparation, 50% bellows respiratory gating, retrospective ECG gating with 50ms temporal resolution). MT-prep consisted of a 1600°, 20 ms Hamming windowed sinc pulse played at 210 Hz to provide both MT and fat saturation. This was compared to a 30 ms, MLEV2 T2-prep with identical imaging parameters. Due to the longer prep time, T2-prep required 9:20 min. Images were reconstructed utilizing non-Cartesian SENSE regularized by the L1-norm of the temporal differences in the 3D wavelet domain. Images were qualitatively compared to 2D breath-held scans. Blood pool to myocardium contrast ratio was computed during end-diastole in the short-axis view at the mid-papillary level.

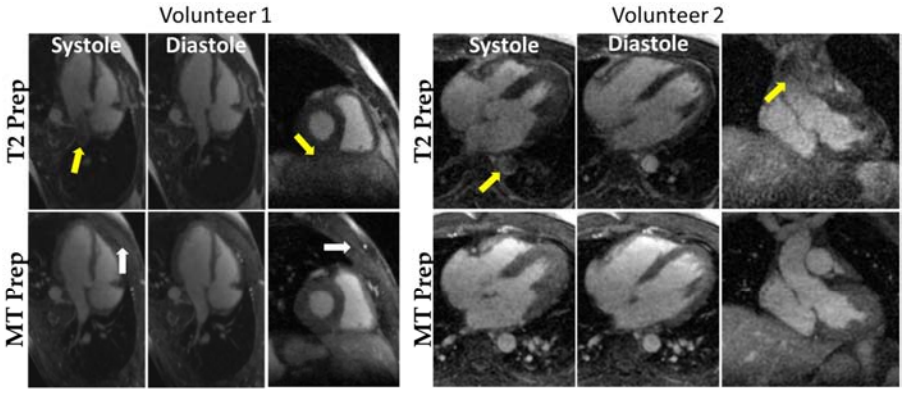

Figure 1. Comparison between 3D sequences in various cardiac views, reformatted from a single acquisition. Yellow arrows – signal dropout in the T2-prep; white arrows – fat saturation in MT-prep.

RESULTS and DISCUSSION: Contrast ratio results were [mean ± std]: 2D [2.9 ± 0.7], T2-prep [3.9 ± 0.3], MT-prep [2.5 ± 0.2]. Figure 1 displays qualitative comparisons between the 3D sequences. Isotropic spatial resolution allows for retrospective whole-heart reformats in any orientation, reducing breath-hold number and eliminating slice-misregistration. T2-prep exhibits signal dropout, particularly during systole. Signal recovers during diastole, indicating flow-induced off-resonance rather than poor refocusing. Conversely, MT-prep does not suffer from these artefacts, evident in volume MIPs (Figure 2) of pulmonary vasculature. MT-prep also provides fat saturation, important in removal of epicardial and chest wall fat contamination while assessing cardiac function.

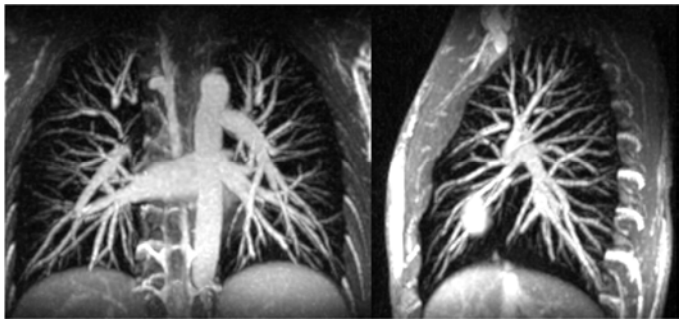

Figure 2. Coronal (L) and sagittal (R) volume MIPs show excellent depiction of pulmonary vasculature.

CONCLUSION: The feasibility of a radial whole-heart functional cardiac acquisition using MT-prep with isotropic spatial resolution is presented. This approach allows for multiplanar reformatting, including the coverage of outflow tracts. Comparisons with standard 2D bSSFP and a T2-prep radial trajectory show reduced but sufficient contrast characteristics for MT-prep with higher robustness to signal dropout artefacts. This approach is also well suited for coregistration with other volumetric acquisitions, such as 4D MR Flow, where information on the dynamic wall motion throughout the cardiac cycle is needed.

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REFERENCES: **1**. Groen, et al. *Eur Radiol.* 2009. **2.** Mascarenhas, et al *AJR.* 2006. **3.** Nezafat, et al *MRM.* 2006. **4.** Stanisz et al. *MRM.* 2005. **5.** Barger, et al. *MRM.* 2002.