Free Breathing 3D Imaging of Right Ventricular Structure and Function using Respiratory and Cardiac Self-Gated Cine MRI

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INTRODUCTION

Cine cardiac MRI, using steady state free precession (SSFP), is an established reference standard for the assessment of cardiac volumes and systolic function. While 2 dimensional (2D) SSFP is widely employed in clinical practice, 3D SSFP offers potential advantages, including contiguous imaging and the elimination of misregistration. Recently, free breathing self-gated 3D acquisition methods have been introduced that enable high resolution imaging even in patients unable to tolerate breath holds. The purpose of this study was to develop and evaluate a free-breathing 3D SSFP imaging method for RV quantification. Accurate assessment of right ventricular (RV) function and volumes is particularly important for patients with heart failure or congenital heart disease, in whom respiratory capacity may be compromised and 2D SSFP not well tolerated.

MATERIALS AND METHODS

2D and 3D cine MRI were performed using a 1.5T (GE HDx) scanner with an 8-channel phased array cardiac coil. 2D cine used a standard segmented SSFP pulse sequence, with each imaging slice acquired during breath-hold. Parameters were: TR/TE = 3.5/1.2ms, flip angle = 60˚, BW = ±125kHz, FOV = 31cm, matrix = 256 x 256, slice thickness / gap = 7/3mm, 12-14 slices, 24 views per segment, 84ms acquired temporal resolution, 28 phases reconstructed. 3D cine used a hybrid radial self-respiratory gated and self-cardiac gated SSFP sequence [1]. Respiratory and cardiac motion parameters were derived from a band-pass filtered center of mass (COM) signal of the projection of the imaging volume onto the slice axis that is acquired repeatedly [2]. 3D cine images were reconstructed using 50% of the data around the peak of the respiratory histogram. Scanning parameters were: TR/TE = 4.4/1.3ms, flip angle = 40˚, BW = ±125kHz, FOV = 31cm, matrix = 256 x 256, slice thickness = 7mm, 14 slices, 14 views per segment, 61.6ms acquired temporal resolution, 61.6ms reconstructed temporal resolution).

The study population comprised subjects without known cardiovascular disease. 2D and 3D cine MRI were performed in random order. For both, short axis RV images were acquired from the tricuspid valve to the pulmonic valve annulus (**Figure 1**) with identical spatial resolution 1.2 x 1.2 x 7mm. 2D and 3D datasets were independently analyzed for RV quantification by an experienced physician blinded to the results of the other imaging method. RV chamber volumes were measured by manual planimetry at end-diastole (RVEDV) and end systole (RVESV) and used for calculation of RV ejection fraction (RVEF). Blood SNR and blood-to-myocardium CNR were measured for 2D and 3D using matched ROIs of RV cavity in relation to the background myocardium. The study was approved by the local institutional review board, and written informed consent was obtained from all subjects.

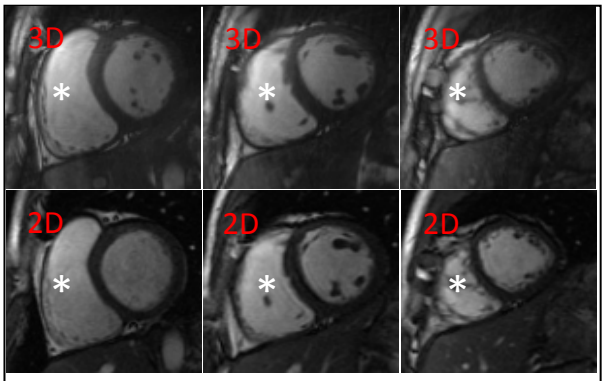

Figure 1. Representative end-diastolic (right) and end-systolic (left) images using 3D free breathing (top) and breath-hold 2D (bottom) cine-MRI. RV noted by asterisk.

	RVEDV	RVESV	RVEF
2D	147.5±25.3	71.4±11.4	51.3±4.7
3D	132.4±22.1	72.5±11.7	45.0±4.9
bias	15.1±8.5	-1±6.4	6.3±2.2
correlation	0.944	0.848	0.893
p-value	0.003	0.43	0.0003

Figure 2. RV functional measurements with breath-hold 2D and self-gated free-breathing 3D cine MRI.

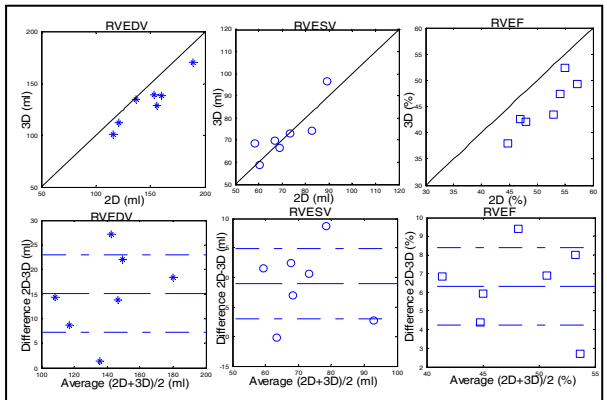

Figure 3 Linear regression and Bland-Altman plots demonstrate the comparative RV quantification using 2D and 3D cine MRI.

RESULTS

7 subjects (32 ± 7 yo, 5 male) were imaged. Both 2D and 3D yielded diagnostic images of the entire RV in all cases. Temporal resolution for 3D imaging was 61.6msec which was lower than that of 2D imaging 29 ± 3.5msec ($p < 0.001$). All RV segments were equivalently graded to have normal regional systolic function. Both SNR (20.6 ± 5.9 vs. 23.1 ± 11.1, $p = 0.2$) and CNR (12.6 ± 2.6 vs. 15.6 ± 8.2, $p = 0.2$) were similar for 3D vs. 2D. **Figure 2** presents RV quantitative measurements, demonstrating similar mean RVESV ($p = 0.43$) but smaller RVEDV ($p = 0.003$) and lower RVEF ($p = 0.003$) by 3D. **Figure 3** demonstrates strong correlations for 3D and 2D quantified RVEDV ($r = 0.94$), RVESV ($r = 0.84$), and RVEF ($r = 0.89$), with larger magnitude of difference for RVEDV (bias 15.1 ± 8.0ml) as compared to RVESV (bias -1.0 ± 6.4ml).

DISCUSSION

These data demonstrate that free breathing 3D cine MRI can comprehensively assess RV structure and function. Whereas RVESV was similar for 3D and 2D, RVESV was smaller by 3D. Differences between methods may be attributable to differences in temporal resolution, z-axis spatial resolution, or misregistration between 2D and 3D cine images of the basal RV. Future study is necessary to improve spatial resolution in slice-direction of 3D cine MRI and test performance for RV assessment in routine clinical practice.

REFERENCES

[1] Liu, et al., MRM 2010; 63: 1230-1237 [2] Larson, et al., MRM 2004; 51: 93-102