Accurate assessment of ventricular volumes in a single breath hold using a 32-channel coil and an extracellular contrast agent.

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Introduction: Functional assessment of cardiac ventricles is an essential aspect of cardiac MR. It provides regional wall motion abnormalities and volumetric data which are important clinical measures. Traditionally cine images are acquired in the short axis (SA) orientation with multiple slices through the ventricles. Although well validated one draw back of this technique is that the multiple slices are acquired during multiple breath holds, which could lead to mis-alignment of the slices and subsequent errors in ventricular assessment. Recently, single breath hold 3D cine techniques have been proposed by using highly parallel imaging [1] or exploiting the spatial-temporal correlations with kt-techniques [2]. However, a major disadvantage of 3D cine acquisitions is the reduced image contrast [3] making the delineation of endo-cardial border difficult. It has been shown that the application of a contrast agent improves the image contrast for volumetric assessment at 3T using a kt-technique [4]. In this study, we propose to evaluate a 3D cine whole heart balanced SSFP sequence on a 1.5T scanner which allows ventricular volume assessment in a single breath hold without compromising accuracy of volumetric analysis. This was achieved using a 32 channel cardiac coil with increased SENSE factors. The loss of myocardial-blood pool contrast due to the 3d-acquisition is overcome by administration of a Gd-DTPA contrast agent (Magnevist®). Comparison of the 3D b-SSFP sequence acquired post injection of contrast with the traditional 2D method showed excellent agreement.

Method: **Data acquisition**: 15 patients attending for routine cardiac MRI were prospectively recruited and scanned using 1.5T MR-scanner (Philips Achieva) with an Invivo 32 channel cardiac coil (two sections with a 4x4 configuration). All patients underwent standard M2D cine SSFP sequence with multi breath holds for volumetric and functional ventricular assessment (SA view, spatial resolution = 2.13x2.14x10mm, 10-12 slices, 21-38ms, SENSE factor 2). Additionally, in each patient a single breath hold 3D-cine b-SSFP sequence (SA view, spatial resolution = 2.13x2.26x10mm, 10-12 slices, 44-56ms, SENSE factor 4) pre and post administration of Gd-DTPA was performed. The post contrast 3D scans were performed immediately after a first pass MR angiogram, i.e. approximately 1 minute after the administration of gadolinium. The 3D cine b-SSFP acquisition was accelerated using SENSE in both phase encoding directions and partial Fourier (factor of 0.625) in the first phase encoding direction.

Data analysis: Two independent observers drew endo-cardial borders manually for the three data sets (2D and 3D pre and post contrast), i.e. both ventricles were segmented in systole and diastole using commercially available software (Philips, Viewforum). Consecutively, end-diastolic volumes (EDV), end-systolic volume (ESV) were calculated, from which the stroke volume (SV) and ejection fraction (EF) were derived. Bland Altman analyses were performed to compare parameters from the 3 groups, M2D, 3D post contrast (3DC) and 3D pre contrast (3DNC). Furthermore, mean contrast between blood pool and myocardium was calculated for all scans

Results: **Data acquisition:** Data was successfully acquired in all patients. Images of the M2D and pre and post 3D images are shown in figure 1. Mean breath hold (BH) duration for the M2D images was 14.9s (12.3-17.2) resulting in approx. 3.5 min for the complete ventricular acquisition (5 BH, 2 slices per BH). In comparison 3D scans required a mean single BH of 20s (18-26s).

Data analysis: Left (LV) and right ventricular (RV) parameters for all 3 scan groups are shown in table 1. Statistical analysis showed no significant difference for measured LV and RV EDV and ESV between the M2D and 3D post contrast (3DC). However, Bland Altman plots showed greater bias and standard deviation (Figure 3&4) when comparing the M2D with 3D images without contrast (3DNC). This was due to less contrast between blood pool and myocardium: M2D 14.66±3.57, 3DC 13.94±5.71, 3DNC 9.18±2.85 and subsequently poorer delineation of endo-cardial borders. Inter and intra observer variability show good reproducibility for these techniques (table 2).

Figure 1: Reformatted Mid Ventricle SA images a) M2D b) 3DC c) 3DNC

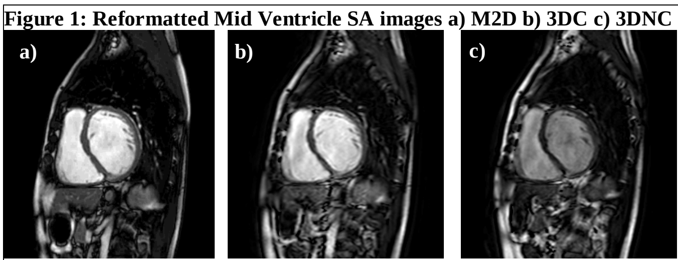


Table 1: LV and RV parameters for the 3 scans M2D, 3DC, 3DNC

Left and Right ventricular parameters						
MRI Technique						
	M2D		3D non contrast (3DNC)		3D contrast (3DC)	
Parameter (ml)	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
LV-EDV	159.3 ± 52.1	94-320	151.1 ± 45.4	93-283	162.7 ± 54.4	93-332
LV-ESV	66.8 ± 45.6	27-187	64.6 ± 46.4	23-189	70.2 ± 49.5	28-208
LV-SV	92.5 ± 21.4	62-133	86.5 ± 20.8	48-127	92.5 ± 22.5	55-130
RV-EDV	161 ± 47.8	71-277	149.2 ± 48.5	48-258	163 ± 46.5	69-268
RV-ESV	70.7 ± 33.3	14-146	67 ± 30.9	14-140	74.7 ± 33.8	17-147
RV-SV	90.3 ± 18.9	57-131	82.2 ± 20.9	34-118	88.3 ± 18.6	52-121

Table 2: Inter observer variability

Inter observer variability for the M2D, 3D non-contrast (3DNC) and 3D contrast methods (3DC).								
	Range difference %				Mean difference %			
	LV EDV	LV ESV	RV EDV	RV ESV	LV EDV	LV ESV	LV EDV	RV ESV
Inter observer M2D	[-12.1 ; 8.3]	[-9.7 ; 17.6]	[-10.6 ; 10.2]	[-9.5 ; 8.0]	-2.1	0.86	1.12	-0.53
Inter observer 3DNC	[-28.3 ; 29.9]	[-2.7 ; 10.7]	[-6.1 ; 11.0]	[-8.4 ; 19.7]	-0.86	3.21	2.17	2.69
Inter observer 3DC	[-10.7 ; 14.1]	[-13.8 ; 16.5]	[-13.8 ; 3.6]	[-9.2 ; 9.5]	-2.75	1.05	-2.89	0.59

Figure 3: Bland Altman LV

(a)EDV 2D vs 3DNC (b) EDV 2D vs 3DC (c) ESV 2D vs 3DNC (d) ESV 2D vs 3D

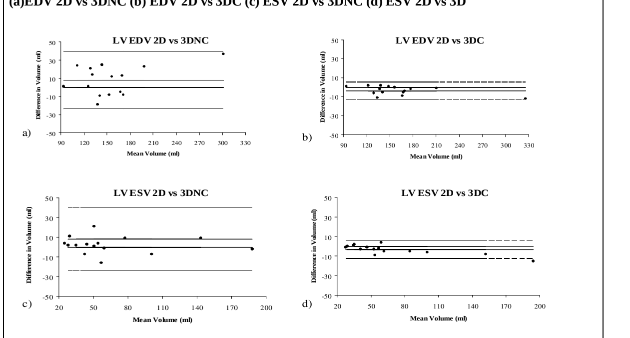
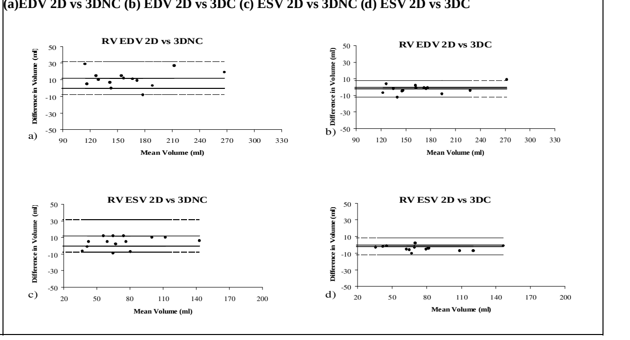


Figure 4: Bland Altman RV

(a)EDV 2D vs 3DNC (b) EDV 2D vs 3DC (c) ESV 2D vs 3DNC (d) ESV 2D vs 3DC



Conclusion: 3D cine b-SSFP imaging of the cardiac ventricles using a 32 channel cardiac coil results in a single breath hold sequence to assess both ventricle volumes. The 4x4 coil configuration allows the utilization of SENSE in 2 directions whilst maintaining good temporal and spatial resolution. Although contrast between blood pool and myocardium is reduced with large SSFP volumes this was significantly improved following administration of contrast agent and results in better delineation of ventricular endo-cardial borders. Future assessment of this 3D sequence would benefit from the use of a blood pool agent to prolong the duration of contrast allowing the sequence to be performed at any stage during scanning. This type of scanning offers a considerable temporal advantage over traditional multi-slice sequences and could prove to be particularly advantageous in less cooperative patients or in stress-studies requiring shorter acquisition times.

References

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