Volumetric Cardiac Quantification Using Three Dimensional Dual Phase Whole Heart MRI

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Introduction: Cardiac ventricular volumes are usually assessed using Simpson's rule over short axis (SA) cines of the heart acquired during breath-holds. This technique is challenging for ill patients and segmentation is difficult due to non isotropic resolution. Recently, a new approach was proposed that calculates the ventricle volumes from two non-angulated isotropic cardiac scans of the whole heart (end-systolic, ES, and end- diastolic, ED) (1). However, this approach results in a relatively long overall scan time. To overcome this limitation we propose acquiring the two volumes in one free-breathing scan using independent navigator beams for each cardiac phase. The aim of this study is to evaluate this new acquisition scheme and compare the EDV, ESV and stroke volumes (SV) obtained using this technique with the traditional multiple 2D (M2D) scans and with flow measurements.

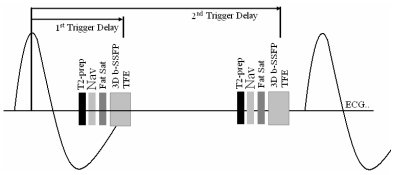

Figure 1. Sequence diagram of the 3D dual phase scan

Method: ***3D dual phase acquisition scheme:*** A 3D triggering b-SSFP turbo field echo sequence was modified to enable the acquisition of two cardiac phases at a user defined time (Fig 1). The sequence was implemented on a 1.5T Philips clinical scanner. A free breathing scan was realized by enabling one navigator beam before data acquisition for each cardiac phase. They were used to prospectively validate or invalidate acquired *k*-space data for each cardiac phase independently. ***Experiments*** A prospective study was performed in ten patients and five healthy volunteers. EDV, ESV and SV were obtained and compared from the following imaging acquisitions, M2D SA cine (res 2x2x8mm, 10-14 slices, 30 ms), free breathing flow scans (resion 2x2x10mm, 30 ms, 3 averages) in the aorta and pulmonary artery and the new dual phase scan (resolution 2x2x2mm, 110-180 slices, 60 ms). The M2D and flow data were analyzed using commercially available software (Philips View forum). Analysis of the 3D data sets were performed using a semiautomatic segmentation (1,2). Bland Altman and T-test analyses were used to assess agreement between the measurements.

Results: ***3D dual cardiac phase scan:*** Reformatted slices in one volunteer are shown in figure 1. The time of the 3D scan was 7:54 ± 1:42 [min:sec], with an scan-efficiency of 47% ± 7% due to respiratory gating. ***Statistical analysis:*** No statistical difference was found for the measured ESV and EDV comparing the 2D and 3D technique (see Bland-Altman plot in figure 3). Bland-Altman plots of SV comparison of the 3D technique with flow measurements and with the M2D method are shown in figure 4. It is noticeable that equivalent results were obtained for both ventricles for all approaches. Range and mean data from intra and inter observer variability using the 3D and the M2D method are shown in table 1.

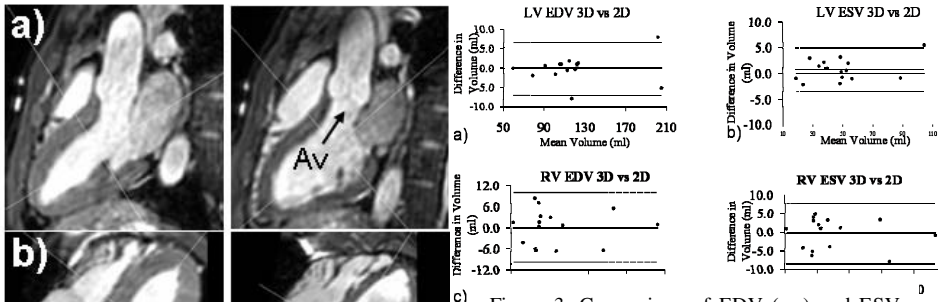

Figure 3. Comparison of EDV (a,c) and ESV (b,d) between the 3D and the M2D method for the LV (a,c) and RV (b,d).

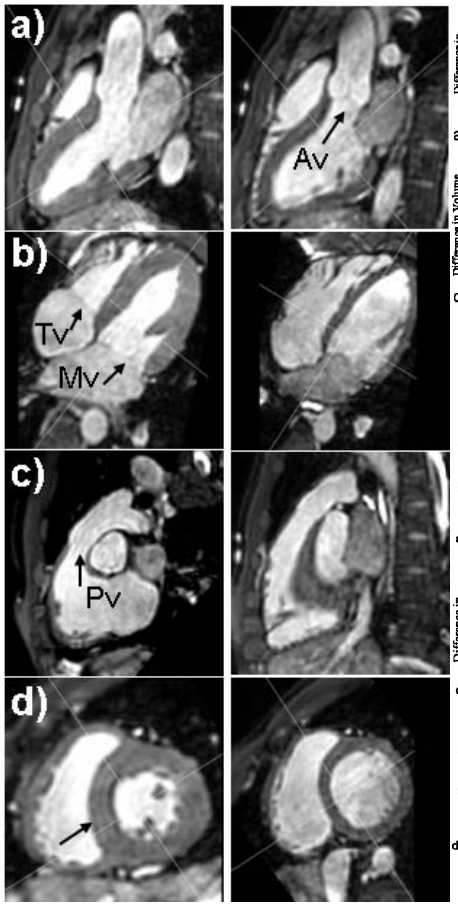

Figure 2. Reformatted images during systole (left) and diastole (right). Arrows show the definition of different valves (a,b,d) and myocardium (d)

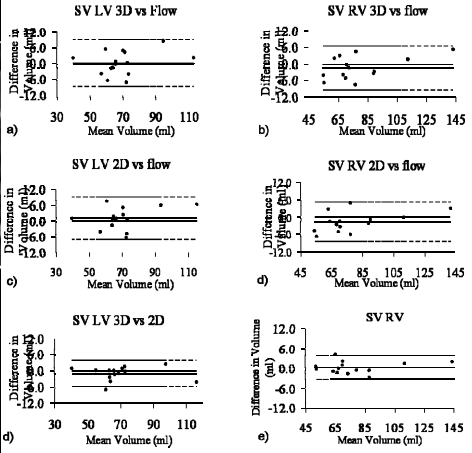

Figure 4. SV comparison between different a,b) 3D vs flow and c,d) M2D vs flows and d,e) 3D vs M2D for LV (a,c,e) and RV

Conclusion: We have introduced an acquisition scheme that allows precise cardiac volume quantification in a single free breathing scan. The new 3D dual phase technique offers a series of advantages over the traditional M2D approach such as minimal scan planning, isotropic resolution and a good definition of the cardiac valves. Severely ill, sedated patients and those with congenital heart diseases may benefit from the proposed method, since it is a patient friendly scan and provides both morphological and cardiac volume information. Intra and inter observer low variability using the 3D method, which would be valuable to reduce the sample size in a large scale study.

Table1	Mean difference (%) / Range difference (%)	
	LV	RV
Intra observer 3D	2.3 / [-7.3 ; 10.6]	-0.9 / [-7.0 ; 2.5]
Inter observer 3D	3.6 / [-11.0 ; 12.5]	6.0 / [-8.3 ; 17.7]
Intra observer M2D	-5.8 / [-30.9 ; 9.1]	-2.6 / [-12.2 ; 9.6]
Inter observer M2D	-5.3 / [-21.9 ; 8.3]	-5.5 / [-19.5 ; 9.8]

References: 1. Greil GF et al. J Magn Reson Imaging 2007. 2. Bottger T et al. Acad Radiol 2007.