Quantitative Assessment of Ventricular Volume from 3D Dual Phase Single Breath–Hold Scan

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Introduction and summary: MRI has emerged as a reliable tool for the evaluation of cardiac function. Usually, several 2D cine b-SSFP short axis slices are obtained in multiple breath-holds and used for assessment of ventricular volumes [1]. This protocol, however, involves a number of issues such as a) misalignment of slices due to different positions of the diaphragm during breath-holds; b) lack of isotropic image resolution due to several mm thick slices; c) planning of short axis cuts requires several steps and d) current segmentation techniques are time consuming with high inter-observer variability particularly because of difficulties in defining the level of the semilunar or atrio-ventricular valves. Here, we present a new approach for ventricular volume quantification. This consists of the simultaneous acquisition of non-angulated end-systolic and end-diastolic 3D b-SSFP volumes in a single breath-hold. Furthermore, volume quantification was performed directly on the 3D volumes [2], thus avoiding any data reformatting. Preliminary results show good agreement between our proposed technique and the standard multi-slice approach for quantification of left ventricular volumes.

Methods: A 3D triggering b-SSFP TFE sequence was modified in order to enable the acquisition of two cardiac phases at a user defined times (See Fig 1a). For both cardiac phases a fat saturation and T2-prep pulses were used to null fat and to increase the contrast between blood and muscle. The modifications were done on a 1.5T clinical scanner (Philips Medical System, Best, The Netherlands) equipped with a 32 channel technology. For signal reception a previously described 32-channel cardiac coil was used [3]. Five healthy volunteer were scanned using ***a)*** a plan scan; ***b)*** a SENSE reference scan; ***c)*** an interactive scan to obtain the geometry of ***d)*** a 2D b-SSFP cine multi-slice short axis view, which was used for volume comparison (5 breath holds of 20 s each, α = 60, TR/TE = 3/1.5, 25 cardiac phases, resolution 2.2x2.2x7 mm, 12 slices, sense 2 AP, partial Fourier 5/8); ***e)*** a dual phase 3D non-angulated scan covering the whole heart and great vessel (21s single breath-hold, α = 60, TR/TE = 3/1.5, 60 reconstructed slices, reconstructed resolution = 2x2x2 mm, acquisition windows of 70-80 ms, sense 2x2 AP RL, partial Fourier 5/8) for which the trigger delays for the two phases were determined from a single 2D cine b-SSFP scan (we used one of the short axis slices obtained during protocol c), although a straight axial slice through the heart could also be used). The same imaging parameters in d) were used to acquire two single phase scans at the ***f)*** end-systolic phase and ***g)*** end-diastolic phase to compare image quality. For the 2D scans end-diastolic and end-systolic volumes were measured using manual segmentation (Viewforum, Philips Medical System, Best, The Netherlands). For the dual phase 3D scans a semiautomatic segmentation technique based on deformable simplex-meshes was used.

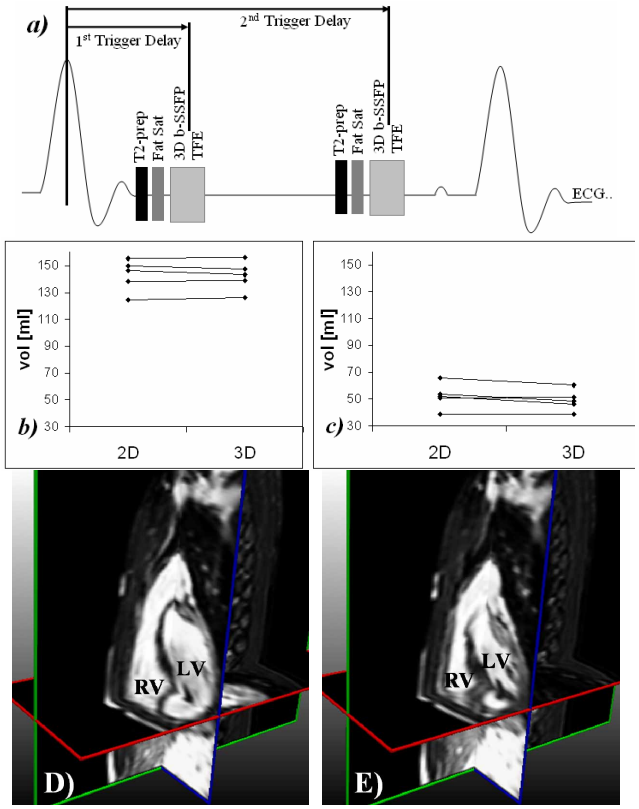

Figure a) Sequence used two acquire 2 cardiac phases at user defined times. b,c) Comparison of end-diastolic (b) and end-systolic volume using the gold standard method and the 3D proposed approach. d,e) 3D views of end-diastolic (d) and end-systolic (e) phases obtained in one volunteer.

Results. A comparison between the ventricular volumes using the standard short axis technique and the dual phase acquisition is shown in Fig. 1 b) for end-diastole and in Fig. 1 c) for end-systole. These graphs show a good agreement between the two techniques. The mean difference in the stroke volume by the two techniques was 3ml (ranging from 0-6 mls). Figure 1d) and e) show 3 reformatted planes of the 3D data set in one volunteer during end-diastolic and end-systolic phases respectively. A qualitative comparison between the dual phase and the single phase 3D scans did not show significant difference in image quality.

Discussion and Conclusion. We have demonstrated the feasibility of quantifying ventricular volume using a 3D dual phase single breath-hold scan. The approach speeds up and simplifies cardiac acquisition and analysis. Advantages include the time saved on not having to plan the short axis view and the reduction in the number of breath-hold scans as well as the availability of isotropic 3D data that is amenable to easier image analysis and hence a semi-automatic and faster segmentation algorithm. Better spatial resolution and reducing the acquisition window may lead to further improvements in accuracy. However this would lead to increased scan time no longer possible in a breath-hold. We are investigating a modified free-breathing higher resolution version of this sequence using navigator beams for respiratory compensation.

References. [1] Miller S. Radiology 2002, [2] Boettger et al, Acad Radiol 2005. [3] Hansen et al, in Proceeding ISMRM 2006.