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Quantification of left ventricular kinetic energy using 4D flow MRI

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Introduction

Three-dimensional, three-component, time-resolved (4D) intracardiac flow can be visualized and quantified with velocity encoded phase contrast (PC) MRI. The kinetic energy content of the blood in the left ventricle (LV) during the cardiac cycle has previously not been described.

Purpose

To develop a method to calculate the kinetic energy during the cardiac cycle of the LV from 4D PC-MRI.

Methods

Six healthy volunteers age 32 ± 11 (mean ± SD), 4 men, were imaged in a 1.5 and 3 T Philips scanner, i.e. two scans per subject in one day. A 4D PC TFE-sequence with retrospective ECG-triggering and respiratory navigator, 3 mm isotropic voxels and a temporal resolution of 25 ms interpolated to 40 phases was used to quantify intraventricular flow. Typical sequence parameters: 1.5 T SENSE factor 2, TE/TR/flip (3.7/6.3 ms/8°). 3 T, SENSE factor 2, TE/TR/flip (3.7/6.2 ms/8°). Cine images from a SSFP sequence (TE/TR/flip, 1.5/2.9 ms/60°) with spatial resolution 1.48 × 1.48 mm, slice thickness 8 mm and a temporal resolution of 30 heart phases, covering the LV in short axis view was used to delineate the endocardial contours. 4D-flow data was post-processed using an in-house developed software including linear background phase correction. PC images were reconstructed from the 4D-data in the short axis view and the endocardial contours were imported and manually corrected when needed. The kinetic energy was calculated as the squared velocity times the mass divided by two for all voxels within the LV for each time point. LV energy values are presented as mean ± SEM and results from the 1.5 T and 3 T measurements were compared according to Bland-Altman analysis (mean ± SD).

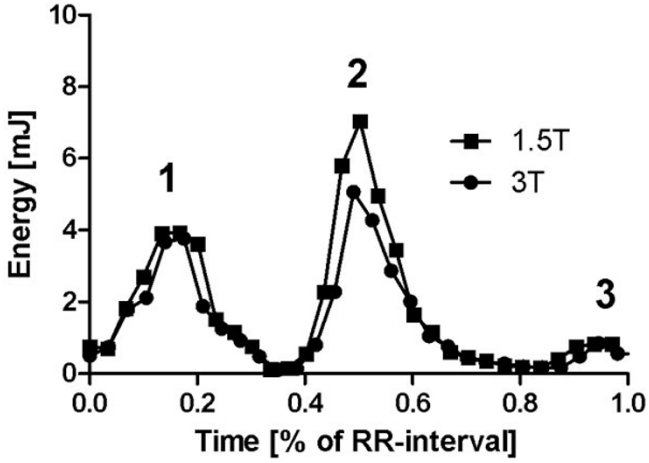

Figure 1
LV kinetic energy over one cardiac cycle in one subject imaged in a 3 T and 1.5 T scanner. Three peaks are seen: 1) early in systole, 2) early diastole and 3) late diastole.

Results

Three distinct kinetic energy peaks during the cardiac cycle was seen in all subjects (Figure 1), one in systole, the largest in early diastole, and one smaller in late diastole corresponding to the atrial contraction. Mean kinetic energy LV energy values were: systolic peak 3.8 ± 0.7 mJ, early diastolic peak 5.5 ± 0.8 mJ and late diastolic peak 1.1 ± 0.1 mJ. Bias between the two MRI scanners were 0.9 ± 1.1, -0.5 ± 1.2 and 0.1 ± 0.2 mJ for the three peaks respectively.

Conclusion

It is feasible to calculate LV kinetic energy using 4D PC MRI. The method showed a low interstudy variability and studies in patients are ongoing.