Quantification of Aortic and Mitral Regurgitation Using Heart Motion Adapted Cine Phase Contrast Flow Measurements

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Introduction
Chronic aortic and mitral regurgitation place an additional hemodynamic load on the left ventricle (LV). Substantial LV chamber dilation, as assessed with echocardiographic techniques, is commonly used as an indirect marker of volume overload. However, for asymptomatic and minimally symptomatic patients the direct measure of regurgitant volume would be the key parameter for patient management. Therefore, a number of studies has aimed at determining regurgitant volumes from volumetric data sets. However, these approaches are only applicable in patients with a single incompetent valve.

Using MR velocity mapping regurgitant flow through heart valves can be directly assessed. In-vitro studies have shown that positioning the imaging slice close to the aortic valve is required to prevent inaccuracies in quantification of aortic regurgitation [1]. However, considerable through-plane motion of the aortic and the mitral valve hampers an accurate positioning of the imaging slice and leads to misregistration of velocities. In order to accurately assess flow through heart valves we recently proposed a method, which adapts the imaging slice position for each heart phase according to the trajectory of the valvular plane of the heart [2]. Velocity data are corrected by subtracting through-plane velocities of valve motion from the measured data.

The objective of the present study was to quantify flow through regurgitant aortic and mitral valves using moving slice velocity mapping in patients.

Methods
Thirteen patients with aortic regurgitation (AR) (mean age: 44.3, range: 28-60, 2 females) and two patients with mitral regurgitation (mean age: 51.5, range: 44-59, males) underwent the MR examinations.

MR measurements were carried out on a Philips Gyroscan NT 1.5T whole body scanner.

Data acquisition: By using a labeling technique to mark basal points of the myocardium and subsequent imaging of the marked points the excursion of the valvular plane was captured [2]. Using image processing the trajectories of markers on the septal and left-ventricular wall were automatically traced. According to the motion of the valvular plane the imaging slice positions for each heart phase of the cardiac cycle were calculated.

Velocity mapping was performed with the following parameters: FOV 256x180 mm², matrix size 256x180, slice thickness 5 mm, venc: 150 cm/s, 75% partial echo sampling, TR: 4.1 ms, trigger delay 40 ms, temporal resolution 25 ms. The velocity encoded and compensated segments were acquired in an interleaved fashion. To achieve time efficient navigator based respiratory motion compensation the Motion Adapted Gating (MAG) approach [3] was implemented. The 2D selective navigator pulse was placed through the right hemi-diaphragm and was applied immediately after R-wave detection. In real-time the k̇ encoding step was calculated according to the actual shift of the diaphragm. Assuming a gating efficiency of 75% and a heart rate of 70 beats/min scan duration was 3:30 min.

For aortic flow measurements velocity mapping with slice adaptation was performed 5 mm downstream of the aortic valve annulus. Flow through the mitral valve was assessed with a moving imaging slice positioned at the mitral annulus.

Data analysis: After background phase correction vessel contours were automatically extracted using active contour based segmentation.

Aortic regurgitant fraction was directly calculated from systolic and diastolic aortic flow. For calculation of mitral regurgitation systolic aortic flow was subtracted from the sum of mitral in-flow and aortic regurgitant flow.

Results
Maximum through-plane displacement of the aortic valve was 7.8±2.5 mm with maximum through-plane velocity of 7.5±1.7 cm/s found during early diastole. The mitral valve exhibited a maximum through-plane displacement of 12.1±2.2 mm with through-plane velocities of as much as 10.1±2.1 cm/s during early diastole.

The apparent regurgitant volume increased by 76.8% (mild AR, n=4), 14.1% (moderate AR, n=7), 8.9% (severe AR, n=2) with correction of the velocity data for through-plane motion. Measured mitral regurgitation increased by 20.2% on average with through-plane motion correction.

Discussion
Using moving slice velocity mapping it is possible to maintain the slice position close to the moving heart valve. Correction of velocity data is required to avoid underestimation of regurgitant volumes. The proposed strategy is also suitable in patients with simultaneous regurgitation of the aortic and the mitral valve.

References