Accurate cardiac valve imaging with optimized workflow

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Motivation:

Dynamic cardiac MR Imaging of the valve planes is an established modality to characterize pathologic changes of the heart valves. To enable the necessary temporal resolution, segmented gradient-echo CINE sequences are used in single breath-held acquisitions [1]. For optimal diagnostic value it is desirable to image the valve plane throughout the complete cardiac cycle. However, due to the complex cardiac motion, the valve plane changes its position and orientation resulting in an incomplete time coverage. A simple but in terms of workflow impractical solution would be a time dependent slice geometry with manual slice position for each of typically 20 heart phases, based on the information taken from a reference CINE scan. The incorporation of an automatized analysis of the slice displacement by tagging, as proposed by Stuber et al. is based on a tagging pattern and requires elaborate automatized image analysis [2]. A reliable and easy-to-handle method is required to address the valve plane motion.

Methods:

A robust method to overcome the effects of heart motion is presented that reduces the required user interaction to define the time-dependent slice geometry. By manual input of two independent slice geometries, representing the two most extreme displacements of the valve plane, based on a suitable interpolation function, all other time frames are calculated. The degrees of freedom slice position, slice orientation and in-plane rotation are incorporated in the interpolation routine. A segmented CINE FLASH sequence (TE 2,5 ms, matrix 192x192, time resolution 52 ms) was modified to enable time dependent slice positioning. The input of two independent slice geometries, based on a reference CINE scan with identical timing acquired in a previous breath-hold, was used to define the two extreme positions and corresponding heart phases of the valve plane. As a first guess for a suitable interpolation function, the first half of a sinusoidal wave was used. As shown schematically in Fig. 1, the zero point at t=0 is assigned to slice 1 as the most basal slice position and the most apical position corresponds to slice 2. The slice geometries, in particular the slice offsets, normal vectors and in-plane rotations of all other time points were calculated based on the interpolation function. Measurements were performed on a clinical 1,5 T MR scanner (Magnetom Avanto, Siemens AG Medical Solutions, Erlangen). In phantom measurements, the correct slice order and geometry of the time-dependent slice positions were verified. In a volunteer measurement, the method was used to image the aortic valve plane. For comparison, a CINE scan without slice following was acquired.

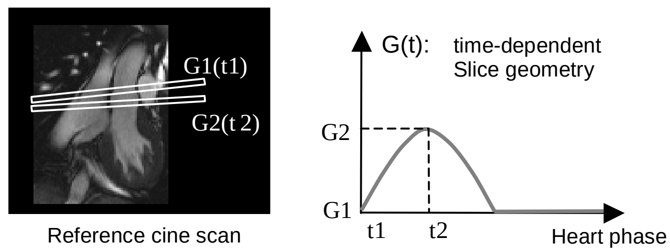

Fig.1: Schematic description of time-dependent slice geometry

Results:

Compared to a single constant slice geometry throughout the cardiac cycle, the slice following technique allowed an improved time coverage of the aortic valve motion. In Fig. 2 the resulting images of two corresponding slices of the same heart phases are shown in comparison. A better alignment of the valve plane represented by clearer visualization of the tricuspidal valve structure as well as a more stable overall slice position in the heart are clearly visible. Despite the input of only two slice geometries, in combination with the selected interpolation function, the valve plane motion can be recovered and therefore be corrected for.

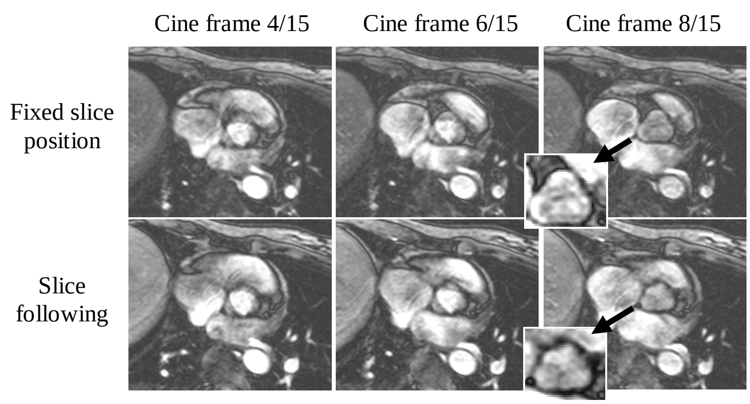

Fig. 2: Selected Cine frames with and without slice following

Discussion:

The slice following method allows for an improved time coverage of the imaged valve plane with little user interaction. However, the underlying interpolation function may not be suitable in all cases, especially in pathologies. Then, a larger number of points of support might also be required to define the time course of the plane motion. This could be controlled in future implementations by assigning the slice geometries of single time points to the corresponding phase of the reference scan and visualization of this assignment in a movie loop. Furthermore, the technique can also be integrated in flow quantification measurements to reduce the remaining inaccuracies due to through-plane motion.

References:

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[2] Kozerke S, Scheidegger MB et al. Magn Reson Med 42:970-978(1999).

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