Three-dimensional myocardial strain analysis with high temporal resolution, using improved HARP tracking

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Introduction: HARP tracking is a fast automatic tool to obtain myocardial strain maps for the early detection of ischaemia. Currently HARP tracking is performed in 2D. Approaches to 3D HARP were presented by Ryf [1] and Li Pan [2]. As yet, it is either not possible to obtain a high temporal resolution [1] or to obtain the complete 3D strain tensor, including the radial strain [2]. Additionally, the original HARP tracking method does not take into account myocardial tissue coming into the image plane due to through-plane motion.

Purpose: To determine the complete 3D myocardial strain tensor with high temporal resolution, based on improved HARP motion tracking in short-axis (SA) and long-axis (LA) image planes.

Methods: *Acquisition.* MR imaging with CSPAMM tagging was performed using SSFP cine imaging, which was applied with a multiple breath-hold scheme to obtain a high temporal resolution of 14 ms [3]. Using 40 time frames, 560 ms of the cardiac cycle was covered. These tagging cines were acquired in five SA and three LA image planes in a healthy volunteer. In the LA planes, the tag planes were adjusted normal to the LV long axis direction.

HARP tracking. In order to track the motion in the SA image planes, the 2D HARP tracking method developed by Osman et al [4] was applied. In contrast to his implementation, a high-pass filter in k-space was used [3]. The resulting displacement-fields were filtered using a moving average filter (kernel size of 5 pixels). To track motion of myocardium entering a SA image plane as a result of longitudinal contraction, inactive points were defined outside the contours, at the first time frame. For each following time frame, the displacement of the inactive points was taken as the displacement of their active neighbours inside the myocardium. Inactive points entering the region between the epi- and endocardial contours were "activated" and tracked during the following time frames.

The tracking of myocardial points on the long-axis images was performed using a 1D HARP tracking method, yielding the longitudinal displacement.

3D strain. The measured longitudinal displacement was used to fit a displacement field throughout the myocardium. For the calculation of 3D motion of myocardial points, the motion trajectories of points on the SA image planes were combined with the longitudinal displacement field. From the resulting 3D motion trajectories of myocardial points, the 3D strain tensor was calculated [5].

Results: The plots represent 3D strain curves versus time. The presented 3D strain parameters are: radial strain (ε_r), circumferential strain (ε_c), longitudinal strain (ε_l), and regional torsion (α_{cl}). These strain parameters are quantified for each temporal frame of 14 ms.

In this 3D strain analysis approach, the spatial resolution in the SA HARP strain maps is optimally conserved. Interpolation and fitting are only used in the longitudinal direction. The early recovery of α_{cl} means that diastole starts with untwisting, as reported earlier [6].

The myocardium moving through the SA image slices due to through-plane motion was successfully tracked, providing new information about myocardial regions that were not studied with the original HARP tracking method during part of the systole.

Conclusions: The presented method yields a complete 3D myocardial strain analysis with high temporal resolution. Because it is based on HARP tracking, no user interaction is required during the tracking process and therefore the method offers prospects for clinical applications that require 3D strain data with high temporal resolution. These applications include the detection of ischaemia, asynchronous contraction and diastolic dysfunction.

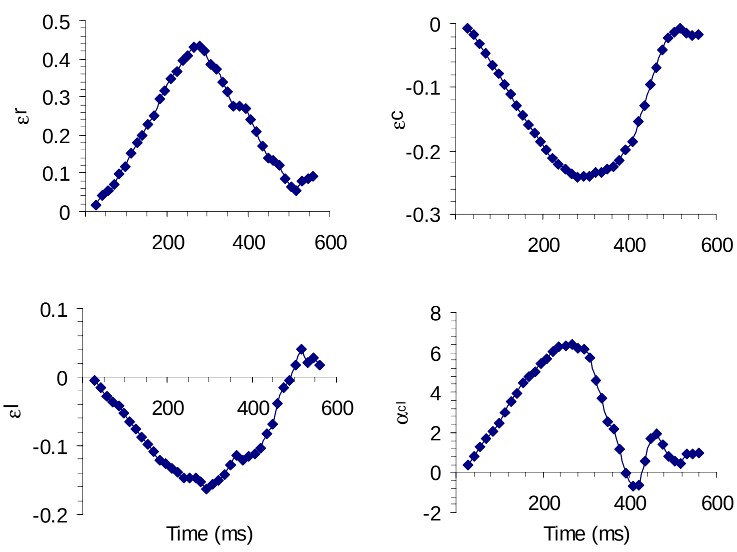

Fig 1. Hight temporal resolution strain curves obtained from a healthy volunteer, resulting from automated 3D strain analysis with HARP tracking.

References

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