Extended Harmonic Phase (HARP) tracking of myocardial motion: effect on observed circumferential shortening

S. R. Tecelao[1], J. J. Zwanenburg[2], J. P. Kuijer[2], J. T. Marcus[2]

[1]Institute of Biophysics and Biomedical Engineering, University of Lisbon, Lisbon, Portugal, [2]Dept of Physics & Medical Technology, VU Medical Centre, Amsterdam, Netherlands

Introduction: HARP Tracking [1] is an automatic tool to track tag points on cardiac tagged images. Due to the combination of longitudinal motion and the conical shape of the heart, new tag lines appear in the short-axis view near the epicardial contour and other tag lines disappear near the endocardial contour during the systolic phase. The original HARP tracking method does not take this myocardial tissue into account.

Purpose: Extension of the HARP tracking algorithm to include tracking of "newly appearing" myocardial tissue and to recover the tag lines that temporarily disappear at the endocardial contour during the systolic phase.

Methods: *Acquisition:* MR imaging with CSPAMM tagging was performed using SSFP cine imaging. The images were acquired with a multiple breath-hold scheme to obtain a high temporal resolution of 14 ms [2]. These tagging cines were obtained in five SA image planes in 6 healthy volunteers. *HARP tracking*: Our method relies on the principle of the tracking algorithm developed by Osman et al [1]. In contrast to his implementation, a high-pass filter in k-space was used [3]. After drawing contours on the harmonic magnitude images, each pixel within the contours was tracked throughout the cardiac cycle. The resulting displacement fields were filtered using a moving average filter (kernel size of 5 pixel). To track the motion of myocardium entering the image plane, "inactive" points were defined outside the contours, at the first time frame. In succeeding time frames, the displacement of the inactive points was taken as the average displacement of the active nearest neighbours. Inactive points entering the region between the epi- and endocardial contours were "activated" and tracked during the following time frames.

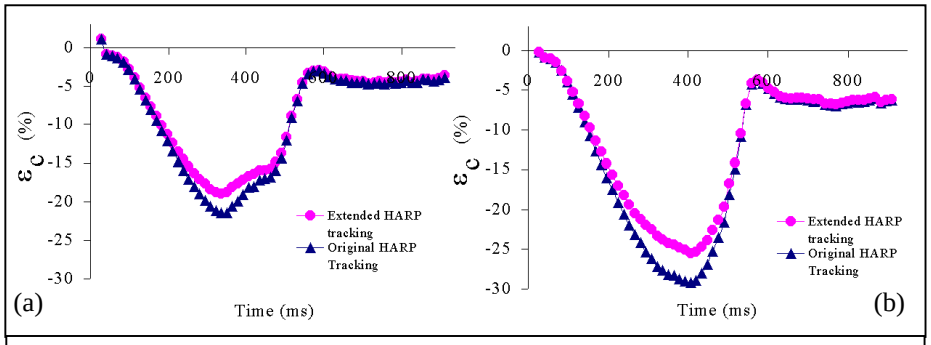

Fig 1: Average circumferential strain at the mid (a) and at the apical (b) slice for each time frame.

2D strain: To compute the circumferential strain, ε_c , homogeneous strain analysis was applied to triangular finite elements connecting the "active" tracked points in each time frame.

Results: Both the original and our extended HARP tracking methods were applied to the mid and apical slices of the volunteer data. An example of the obtained circumferential strain curves is shown in Fig 1. It is shown that there is less circumferential shortening when the new tissue coming into the image plane is taken into account. Averaged over all subjects, the circumferential strain decreases by 1.9±0.7 % for the mid slice (a relative decrease of 8.9±2.9 %), and by 3.0±1.1 % for the apical slice (a relative decrease of 11.3±3.4%). The difference between the number of tracked points with each version is represented on Fig 2 for the same subject as in Fig 1. With extended tracking 64% more points are included at the apex, and 55% at mid level, at end systole. Fig 3 shows the difference in average circumferential strain related to difference in average radial position for each time frame, for the same subject. The correlation coefficients are 0.96 for the mid slice and 0.91 for the apical slice.

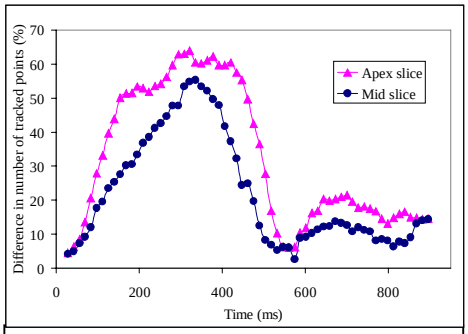

Fig 2: Difference in the number of tracked points between extended and original version of HARP tracking, for the mid and apical slice.

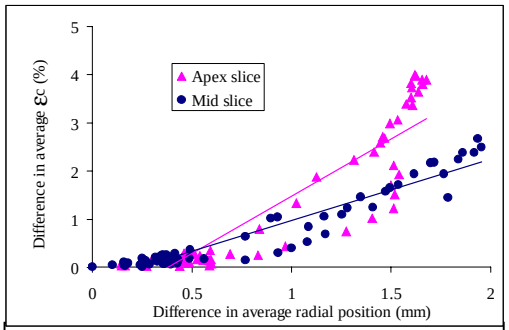

Fig 3: Difference in circumferential strain versus difference in radial position, between extended and original HARP tracking. When the averaged radial position of the tracked points is larger (i.e. more points near the epicardium), the calculated strain is less negative. Each plotted datapoint presents the average value for each time frame at mid and apical slice.

Discussion: Tracking of "newly appearing" tag lines decreases the systolic circumferential shortening. Presumably, when the new tag lines are not tracked, the observed strains are biased towards the endocardium, which contributes for the higher circumferential strain. The difference in the number of tracked points is larger for the apical slice due to the higher amount of new tissue appearing on this slice compared to the mid one.

Conclusion: We conclude that disregarding "newly appearing" tissue leads to systematic errors in the observed strains. The myocardium moving into and through the SA image slices can successfully be tracked, providing new information about myocardial regions that were not studied with the original HARP tracking method.

References

[1] Osman, et al. Mag Res Med 1999; 42: 1048-1060 [2] Zwanenburg JJM, et al. Mag Res Med 2003; 49:722-730 [3] Kuijer JPA, et al Mag Res Med 2001; 46:993-999

Acknowledgment

Supported by the Portuguese Foundation for Science and Technology, grant nr. SFRH/BD/3005/2000 and by the Netherlands Heart Foundation, grant nr. 2000B220