Mapping myocardial mechanical activation by MRI tagging and HARP

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Introduction: Evaluation of heart mechanical dyssynchrony is important in selecting dilated cardiomyopathy (DCM) patients who benefit from cardiac resynchronization therapy [1][2][3]. In this study we present a MR tagging-HARP method [4] for myocardial mechanical activation monitoring. Feasibility of the proposed approach was tested on small subject population.

Materials and methods: Six subjects (3 healthy with normal ECG and 3 DCM with QRS duration > 120 ms) underwent MR acquisition. Basal, medium and apical tagged MR images of the left ventricle (LV) were acquired with a high temporal resolution (14 ms) on a GE 1.5T scanner using a fast GRE pulse sequence (slice thickness 8mm; FOV 380 x 380; matrix size 256 x 160). The spatial modulation of magnetization yields a pattern with tag spacing of 7 pixels. Using cine MR imaging (SSFP), a three-chamber view (3C) was acquired with the same temporal resolution (14 ms) to define the times of aortic and mitral valves opening (Tavo and Tmvo, respectively) and the time of aortic valve closure (Tavc) [3]. Tagged MR slices were analysed by HARP method. Circumferential strain (Ecc) was computed at midwall in six segments at basal and medium levels and in four segments at apical level . Ecc signal was filtered using a moving average filter of 3 sample widths and strain rate (SR) signal was computed. Two mechanical indexes were derived. The onset of shortening (Tshor) was defined as the first positive to negative zero crossing of strain rate [2]. The onset of deformation (Tonset) was evaluated by examining SR between two selected points ($SR_{1\text{-}2}$). The first one was defined as the zero value of SR (1) around Tavo. The second one was defined as the first Ecc peak (2), after Tavo and the first point, with amplitude larger than 5% of the maximum Ecc peak amplitude. Tonset was computed as the time where $SR_{1\text{-}2}$ began larger than a fixed threshold (15% of maximum $SR_{1\text{-}2}$) (Fig.1). Both indexes were normalized with respect to cardiac cycle duration.

Results: For each segment, a mean Tonset and Tshor were calculated among healthy and DCM subjects. Cumulative myocardium activation plots (CMAP) were obtained. The times of 10% and 90% of myocardium activation (Act10, Act90 respectively) were also evaluated (Fig.2A and Fig.2B). Time delays between Act10 points in Tonset and Tshor CMAPs were 0.022±0.008% and 0.011±0.01% in healthy and DCM subjects, respectively. Time delays between Act90 points were 0.024±0.01% and 0.18±0.12% in healthy and DCM subjects, respectively.

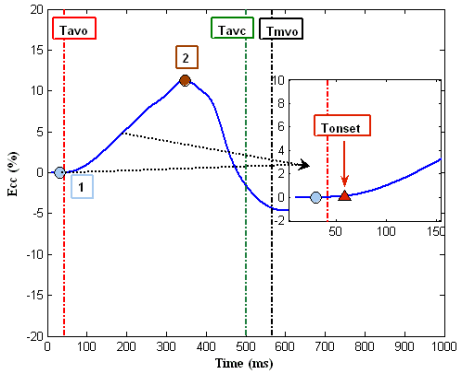

Fig 1: Tonset definition in patient with dilated cardiomyopathy (DCM).

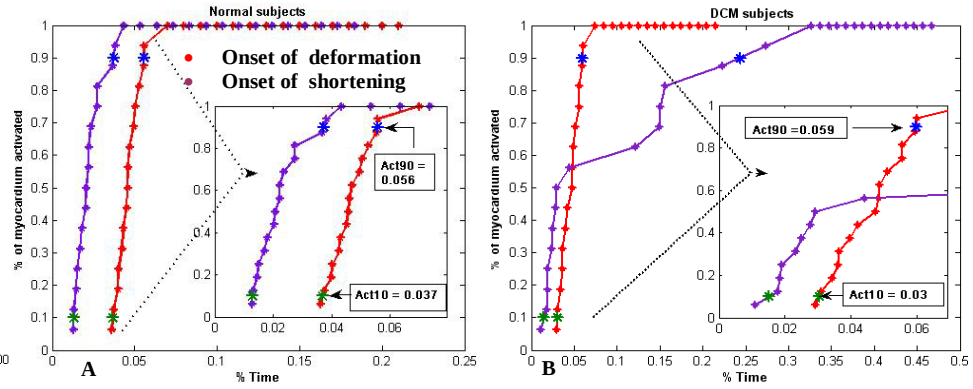

Fig 2: Comparison between cumulative myocardium activation plots in normal and DCM subjects.

Discussion: In healthy subjects, the CMAP curves showed the same pattern with a constant delay between Tonset(s) and Tshor(s) (Fig.2A). In DCM patients (Fig.2B), CAMP obtained using Tonset has the same trend as normal case. Tshor CAMP showed a delayed activation of some cardiac segments, likely due to mechanical dyssynchrony. In conclusion, MR tagging seems to be a promising technique for effective monitoring of myocardial mechanical activation.

References: [1] Bradley T.W. et al., Am J Physiol Heart Circ Physiol 1999;276:H881-H891. [2] Kirn B. et al. Am J Physiol Heart Circ Physiol 2008;295:H640-H646. [3] Zwanenburg J.J.M et al. Am J Physiol Heart Circ Physiol 2004;286:1872-1880. [4] Osman N.F., IEEE Trans Med Imaging 2000;19(3):186-202.