A quantitative comparison between 2-dimensional and 3-dimensional circumferential strain in the human heart

S. R. Tecelão[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 University Medical Center, Amsterdam, Netherlands

<u>Introduction</u>: Cardiac resynchronization theraphy (CRT) is a new surgical treatment for patients with heart failure (HF) and left bundle-branch block (LBBB). Due to the complexity of this type of intervention and its associated costs, it is important to predict with high accuracy which patients will benefit from it. Recent studies suggest that mechanical dyssynchrony should be assessed instead of electrical dyssynchrony [1] and that the dyssynchrony measured on the circumferential direction is more accurate than measured on the longitudinal direction [2].

<u>Purpose</u>: To evaluate the difference between the 2D and 3D circumferential strain assessed with MR tagging.

<u>Methods</u>: *Subjects:* Six healthy volunteers and 5 asymptomatic patients with left bundle-branch block (LBBB) were evaluated. *Acquisition:* MR imaging with complementary SPAMM (CSPAMM) tagging was performed with steady state free precession (SSFP) sequence using the linearly increasing startup angle approach (LISA) [3]. Five equidistant SA planes were obtained between base and apex and three LA planes with an angular spacing of 60º were imaged perpendicular to the SA. A multiple expiration breath hold scheme was performed in order to avoid mismatching between the several images acquired per set (images with sinusoidal and inverted sinusoidal tagging for CSPAMM computation). *2D circumferential strain analysis*: From the CSPAMM images, the harmonic magnitude (HARM) and harmonic phase (HARP) images were computed [4]. After drawing the myocardial contours on the HARM images, the automatic extended HARP tracking method [5] was applied to the HARP images in order to track the myocardial tissue inside the contours. To compute the 2D circumferential strain, a homogeneous strain analysis was applied to triangular finite elements defined with the tracked myocardial points on each time frame at the basal, mid and apical levels. *3D circumferential strain:* The automatic 3D extended HARP tracking method was applied to the HARP images to track the myocardial tissue inside the contours. The 3D displacement of the myocardial points was obtained by combining the trajectories on the SA image planes with the trajectories on the LA image planes [6]. From the tracked positions of the five SA image planes, a mesh of tetrahedrons was defined at each time frame and the circumferential strain was obtained. *2D vs 3D circumferential strain:* The 2D and 3D timing of shortening were compared (time to onset of circumferential shortening, T_{onset} and time to maximum peak of shortening, $T_{peak,max}$; in patients also the time to the first peak of circumferential shortening ($T_{peak,first}$) was compared). Additionaly, 2D and 3D maximum peak of circumferential shortening were compared, as well as the first peak of circumferential shortening for the LBBB population. Finally, the cross correlation between the 2D and 3D strain curves was computed.

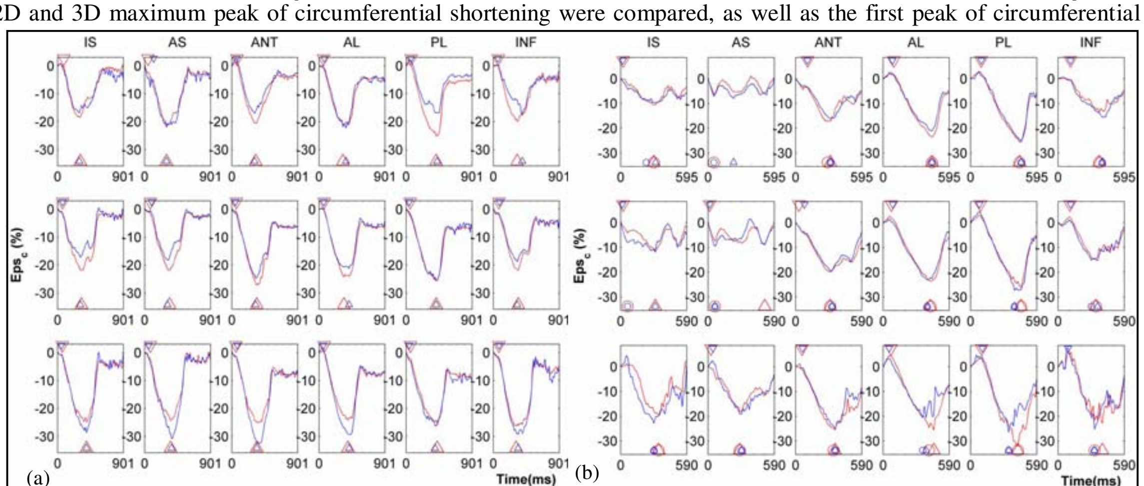

Fig. 1 Example cuve of the 2D (blue line) and 3D (red line) circumferential strain (Eps$_c$) for an healthy volunteer (a) and LBBB patient (b). ∇ - 2D (blue) and 3D (red) T_{onset} ; △ - 2D (blue) and 3D (red) $T_{peak,max}$; O - 2D (blue) and 3D (red) $T_{peak,first}$; IS - infero-septal; AS – antero-septal; ANT – anterior; AL – antero-lateral; PL – pos-lateral; INF – inferior.

<u>Results</u>: Comparing the 2D and 3D timing and peaks of shortening using the multilevel analysis, it was found that there is no significant difference between these parameters for both populations, except for the $T_{peak,max}$ of the healthy subjects. In this case, the 2D strain analysis method detected the circumferential shortening peak slightly later (13 ms) than the 3D method (P= 0.04). For both populations the maximum r^2 (square of max. cross-correlation between the 2D and 3D circumferential strain) was high: 0.97 ± 0.04 and 0.87 ± 0.16 for the healthy and LBBB population respectively, which shows a good similarity between the 2D and 3D circumferential strain curves. The mean delay at maximum cross correlation was 1.1 ± 4.2 ms for the healthy population and -0.2 ± 8.3 ms for the LBBB population. The strain plots in Fig. 1 show that for the first time frames there is no difference between the 2D and 3D circumferential strain. As the deformation of the myocardium increases, this difference increases, reaching a maximum near end systole.

<u>Discussion</u>: Only the difference found between the 2D and 3D $T_{peak,max}$ of the healthy population was statistically significant, however, we think that this difference is negligible since it is smaller than the time resolution of our images (14 ms). The high positive correlation coefficients obtained between the 2D and 3D circumferential strain, show that there is a good similarity between both computation methods. The small differences observed between the 2D and 3D circumferential strain (seen in Fig 1.) can be explained from practical problems to compare exactly the same piece of myocardium.

<u>Conclusion</u>: We conclude that there is no significant difference between the 2D and 3D circumferential strain. Being the 2D strain computation less time consuming, circumferential shortening should be measured using this approach.

<u>References:</u> [1] Nelson et al. Circulation 2000; 101:2703-9 [2] Helm et al. Circulation 2005;111:2760-2767 [3] Zwanenburg, et al. Mag Res Med 2003; 49:722-730 [4] Osman, et al. Mag Res Med 1999; 42: 1048-1060 [5] Tecelão et al. Proc 13th Annual Meeting ISMRM, 2005, p. 332 [6] Kuijer, et al. Mag Res Imag 2000; 18:553-564

<u>Acknowledgement:</u> Supported by Calouste Gulbenkian Foundation, the Portuguese Foundation for the Science and Technology, grant nr. SFRH/BD/3005/2000 and by the Netherlands Heart Foundation, grant nr. 2000B220