4D Right Ventricular Strain in Pulmonary Hypertension and Normals

B. Ambale Venkatesh[1], S. G. Lloyd[2], M. I. Ahmed[2], H. Gupta[2], L. Dell'Italia[2], and T. S. Denney Jr.[1]
[1]Electrical and Computer Engineering, Auburn University, Auburn, Alabama, United States, [2]University of Alabama at Birmingham

Introduction

Accurate assessment of right ventricular (RV) function is clinically important – particularly in patients with pulmonary hypertension (PHTN). Compared to the LV, however, analysis of RV function is relatively difficult. Unlike the LV, the RV does not have geometric symmetry. Also, in PHTN, higher systolic blood pressure in the RV can cause excursion of the interventricular septum into the LV cavity. As a result, the LV cavity can also loose it geometric symmetry. In this abstract, the discrete model-free (DMF) method [1] was used to reconstruct three-dimensional (3D) biventricular strain in each imaged timeframe from displacement measurements obtained from tagged MRI by an unwrapped phase technique [2]. We refer to this method as the unwrapped phase DMF (UPDMF) technique. The advantage of the DMF technique is that it makes no assumptions about the shape of the tissue being analyzed. The unwrapped phase technique produces dense displacement measurements at each time with minimal manual intervention. Results are presented in both normal volunteers and PHTN patients

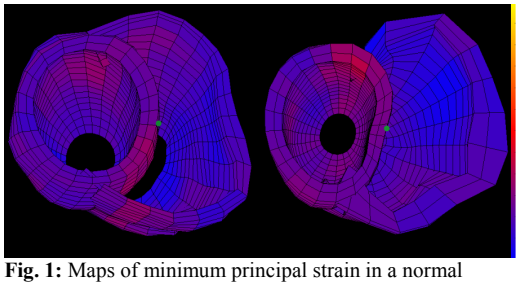

Fig. 1: Maps of minimum principal strain in a normal human volunteer (left) and PHTN patient (right). Strains are mapped from blue = -30% to yellow = 30%.

Procedure

All procedures were performed per institutional guidelines after obtaining informed consent. Normal participants (n=5) and PHTN patients (n=5) were imaged. Images were acquired on a GE 1.5T system optimized for cardiac application. Standard short-axis cardiac views were obtained. Six, equally-spaced, radially-oriented long-axis views were obtained, which resulted in 2-3 long-axis slices through the RV free wall. Both cine and tagged images were acquired with a fast gradient-echo cine sequence with the following parameters: FOV = 300 mm, image matrix = 224x256, flip angle = 45º, TE = 1.82ms, TR = 5.2ms, number of cardiac phases = 20, slice thickness = 10 mm. A 2D spatial modulation of magnetization tagging preparation was done with a tag spacing of 7 pixels.

3D LV displacement measurements were measured from unwrapped HARP phase using the method described in [2]. Myocardial contours were semi-automatically drawn at end-diastole (ED) and end-systole (ES) timeframes for all slices and then propagated to all time frames [3]. The DMF technique [1] was used to reconstruct 3D biventricular strains at each imaged timeframe from 1D displacement measurements. This processing took approximately 30min per study.

The 3D UPDMF strains were validated by comparing them to 3D strains computed using feature-based DMF (TagDMF) [4] at ED and ES and 2D strains computed using HARP [5]. Paired t-tests, correlation coefficients, and coefficients of variation were used to compare strains. P-values less than 0.05 were considered statistically significant.

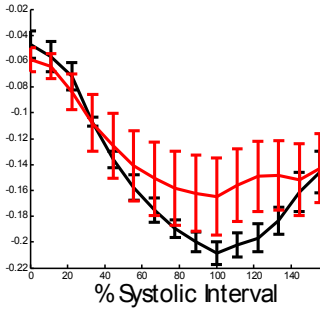

Fig. 2: Plots of average mid-ventricular RV maximum shortening measured using UPDMF in normal volunteers (black) and PHTN patient (red). Error bars represent ± one standard error.

Results and Discussion

Table 1 shows a comparison of strains obtained using the UPDMF and TagDMF methods. The differences were not statistically significant, the strains are highly correlated, and the coefficient of variance is less than 6%.

Table 1: Comparison of differences between UPDMF and TagDMF RV strains (UPDMF-TagDMF). All correlation coefficients (ρ) are statistically significant. E_{tt} = tangential strain. E_{ll} = longitudinal strain. E_{min} = maximum shortening.

Strain	M	±	STD	P	ρ	CV (%)
E_{tt}	0.0371	±	0.0059	0.11	0.93	5.5
E_{ll}	0.0276	±	0.0055	0.19	0.93	3.7
E_{min}	0.0041	±	0.0059	0.84	0.95	2.5

Table 2 shows a comparison of strains obtained using UPDMF (3D) and HARP (2D) methods. The peak strain and systolic strain rate of the measured strains show a high correlation. Also, the tag line CNR decreases through the cycle due to T1 decay of the tag pattern, so early diastolic correlations are lower than correlations for peak strain and systolic strain rate. The 3D vs 2D correlations were lower and the differences larger when compared to the 3D vs 3D values in Table 1. This could be attributed to the differences in 3D vs 2D strains.

Table 2: Comparison of differences between UPDMF and HARP RV strains in the RV (UPDMF-HARP). * Correlation coefficient (ρ) P<0.05. E_{tt} = tangential strain. E_{min} = maximum shortening.

	Strain	M	±	STD	P	ρ	CV
Peak	E_{tt}	0.0287	±	0.0028	0.1254	0.7692*	0.0753
	E_{min}	-0.0224	±	0.0030	0.2902	0.8090*	0.0434
Systolic	E_{tt}	0.0703	±	0.0191	0.5443	0.7286*	0.0810
Rate	E_{min}	-0.1935	±	0.0218	0.2000	0.8544*	0.0784
Early Dia	E_{tt}	-0.3768	±	0.0604	0.1119	0.2906	0.1923
Rate	E_{min}	-0.0913	±	0.0247	0.4940	0.6666*	0.1165

Fig. 1 shows maps of end-systolic minimum principal strain in a normal volunteer and patient with PHTN. Note the excursion of the interventricular septum into the LV in the PHTN heart. Plots of RV maximum shortening (negative of minimum principal strain) are shown in Fig. 2 for PHTN and normals. It is clear that shortening is suppressed in PHTN's compared to normals.

Conclusions

Three-dimensional RV strain can be measured in both normal volunteers and PHTN patients from end-diastole to mid-diastole.

References

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