3D+t Biventricular Strain from Tagged Magnetic Resonance Images by Phase-Unwrapped HARP

B. Ambale Venkatesh[1], H. Gupta[2], S. G. Lloyd[3], L. Dell' Italia[3], and T. S. Denney Jr. [4]
[1]Electrical and Computer Engineering, Auburn University, Auburn, Alabama, United States, [2]University of Alabama at Birmingham, United States, [3]University of Alabama at Birmingham, [4]Auburn University

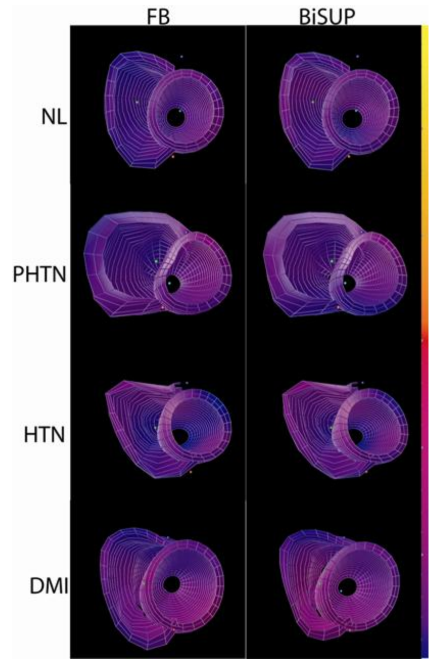

Fig. 1: Maps of maximal shortening strain using BiSUP and FB methods for a representative heart from each group. Strains are mapped from blue = -25% to yellow = +25%.

INTRODUCTION

Accurate assessment of ventricular function is clinically important in the diagnosis and treatment of heart failure. In last year's conference [1], a method to compute 3D right ventricular (RV) strains in normal and pulmonary hypertension (PHTN) hearts was presented. A discrete model-free (DMF) method [2] 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 [3]. In this abstract, we validate the method to compute 3D+t biventricular strain from unwrapped phase (BiSUP) with four different patient groups.

PROCEDURE

The BiSUP algorithm was validated on a cohort of 30 human subjects: 10 normal volunteers (NL), 7 patients with pulmonary hypertension (PHTN), 8 patients with resistant systemic hypertension (HTN) and 5 diabetics with recent (within 2 weeks) myocardial infarction (DMI). All procedures were performed per institutional guidelines after obtaining informed consent. 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. Fast gradient-echo cine tagged images were acquired 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, 2D spatial modulation of magnetization tagging preparation with tag spacing 7 pixels.

3D displacement measurements were measured from unwrapped harmonic phase (HARP) using the method described in [3]. The DMF technique [2] was used to reconstruct 3D biventricular strains at each imaged timeframe from 1D displacement measurements. This processing took approximately 90 min per study including approximately 60 minutes of user interaction and 30 continuous minutes of unsupervised strain computation. The BiSUP strains were validated by comparing them to 3D strains computed using feature-based DMF (FB) [4] at ES and 2D HARP strains [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.

RESULTS AND DISCUSSION

Table 1 shows a comparison of strains obtained using the BiSUP and FB methods. The differences were not statistically significant in the LV. The tangential strain in the RV was found to be significantly different, probably because of the higher number of measurements obtained using BiSUP. The strains are highly correlated, and the coefficient of variance is less than 4%. Fig. 1 shows maps of end-systolic maximal shortening strain measured using the FB and BiSUP methods for a representative heart from each group. The strain maps are similar. Fig. 2 shows the comparison of strains over time using the BiSUP and HARP methods. The curves show good agreement.

CONCLUSIONS

BiSUP, a method for measuring 3D+t bi-ventricular strain in a reasonable amount of time, was found to be accurate and capable of measuring strains in hearts of different pathologies and morphologies.

Table 1: Comparison of 3D, end-systolic strains computed from strain from unwrapped phase (BiSUP) and feature-based (FB) methods. p<0.001 for all correlations. E_{cc} = circumferential shortening, E_{ll} = longitudinal shortening, E_{min} = maximum shortening. E_{tt} = tangential shortening.

Strains	Difference (BiSUP-FB)	p	ρ	CV
E_{cc}	*0.0095 ± 0.0019*	*0.18*	*0.93*	*2.01%*
E_{ll}	*0.0046 ± 0.0018*	*0.63*	*0.97*	*1.62%*
E_{min}	*0.0048 ± 0.0022*	*0.56*	*0.93*	*1.59%*
Torsion (deg)	*-1.8019 ± 0.2461*	*0.10*	*0.97*	*3.01%*
E_{tt}RV	*0.0212 ± 0.0026*	*0.03*	*0.93*	*3.11%*
E_{ll}RV	*0.0151 ± 0.0025*	*0.15*	*0.95*	*2.31%*
E_{min}RV	*0.0154 ± 0.0021*	*0.13*	*0.96*	*1.51%*

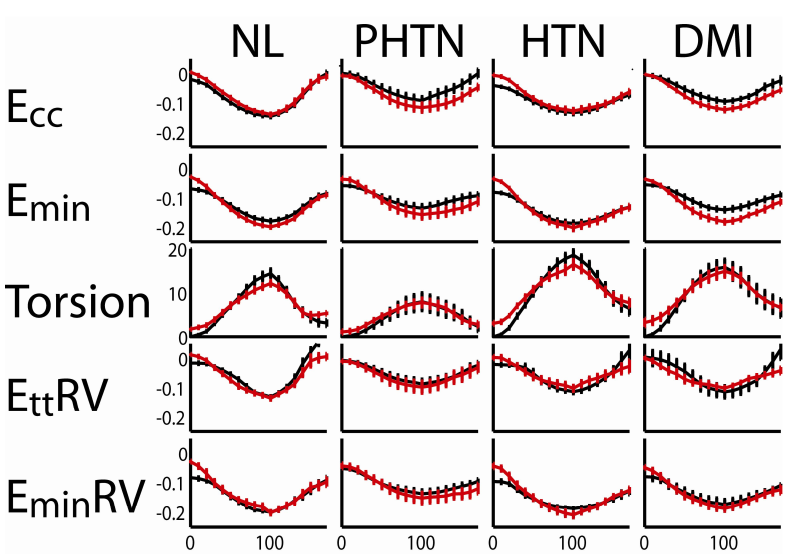

Fig. 2: Plots of average mid-ventricular strain and torsion measured using BiSUP (red) and HARP (black) methods. Error bars represent ± one standard deviation.

REFERENCES

[1] Ambale, et al. *Proc. ISMRM* 2010.
[2] Denney and McVeigh. *J. Magn. Res. Imag.,* 7:799-810, 1997.
[3] Ambale, et.al. *J. Magn. Res. Imag.,* 4:854-862, 2010.
[4] Ambale, et al. *Proc. ISMRM* 2008.
[5] Osman and McVeigh. *Trans. Med. Imag.,* 19(3):186-202, 2000.