3D Right Ventricular Strain and Geometry in Pulmonary Hypertension and Normals

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INTRODUCTION

Accurate assessment of right ventricular (RV) function is clinically important – particularly in patients with pulmonary hypertension (PHTN). Compared to the left ventricle (LV), however, analysis of RV function is relatively difficult. Unlike the LV, the RV does not have geometric symmetry, precluding use of simple geometric models to calculate RV volumes and wall stress. Also, in PHTN, higher systolic blood pressure in the RV can cause excursion of the interventricular septum into the LV cavity as seen in Fig 1. As a result, the LV cavity can also lose its geometric symmetry. In this abstract, the discrete model-free (DMF) method [1] is used to reconstruct three-dimensional (3D) biventricular strain. The advantage of the DMF technique is that it makes no assumptions about the shape of the structure/tissue being analyzed. Results are presented in both normal volunteers and PTN patients.

METHODS

All procedures were performed per institutional guidelines after obtaining informed consent. Normal participants with no known cardiac disease (n=3) and PHTN patients (n=8) were imaged. Cine images were acquired on a GE 1.5T system using ECG gated steady state free precession (SSFP) technique with the following parameters: slice thickness 8mm, Field-of-view 40×40 cm, scan matrix 256×128, flip angle 45°, TR/TE = 3.8/1.6ms, temporal resolution < 50ms. Standard short-axis cardiac views were obtained. Six long-axis views were obtained along the long axis of the LV with different angular oblique orientation around this axis, each spaced 30° apart as shown in Fig. 1. Tagged images were acquired with a fast gradient-echo cine sequence with the slice prescription described above and 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.

3D LV geometric parameters were measured from RV and LV contours manually traced on cine images acquired near end-diastole and end-systole. The contours were traced to exclude the papillary muscles. B-spline surfaces were fit to the contours and standard formulas were used to compute local curvatures. Tags were tracked and contours identified in both the RV and LV walls semi-automatically. The DMF technique [1] was used to reconstruct biventricular strains. This method constructs a high-resolution 3D segmentation of the myocardium from the contours and uses a Cartesian-based smoothness assumption to reconstruct cardiac deformation and strain. Strain and geometric parameters were compared at the proximal/basal, middle, and distal/apical thirds of the RV septum and free walls with a standard t-test. A P-value of 0.05 was considered statistically significant.

RESULTS AND DISCUSSION

Fig. 2 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 systolic maximum shortening (negative of minimum principal strain) and systolic local curvature tangential to the wall from the short axis planes are shown in Fig. 3 All curvatures were computed relative to the LV central axis such that normal curvatures are positive in all regions, a locally flat wall would have zero curvature, and significant septal wall excursion into the LV cavity would result in negative curvature. Both strain and curvature parameters were averaged over the RV septal and free walls at the proximal/basal, middle, and distal/apical thirds of the walls. Only two statistically significant differences were found, likely due to the small sample sizes, but several interesting trends were observed. Shortening is depressed in PHTN compared to normals in both the RV septum and free walls. Also, shortening increases from the proximal to distal thirds in normals, but is relatively constant in PHTN. The tangential curvature in the septum is lower in PHTN compared to normal because the increased RV pressure causes the septal wall to flatten or even protrude into the LV cavity. The flattening of the septum, however, is greatest in the third proximal to the base and goes to normal in the distal third. Tangential curvature is also decreased in the distal third of the RV free wall due to bulging of the RV in this region.

CONCLUSIONS

Here we demonstrate a simple methodology, which does not rely on any geometric assumptions of the ventricular shapes, to assess the curvature and wall strains of the left and right ventricles. We show that the method is useful for detecting small changes in these parameters even in the altered ventricular geometry seen in PHTN. The method should have applicability in a wide range of pathologic conditions affecting ventricular shape and function.

REFERENCES

[1] T. S. Denney Jr. and E. R. McVeigh. Model-free reconstruction of three-dimensional myocardial strain from planar tagged MR images. J. Magn. Res. Imag., 7:799--810, 1997.

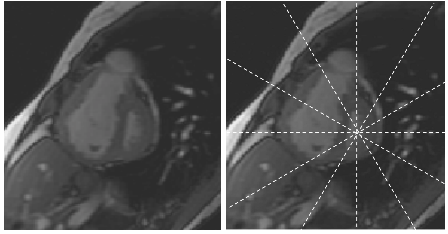

Fig. 1: Left: Basal short-axis slice of a PHTN patient near end-systole showing RV excursion. **Right:** Same image with long axis prescriptions shown.

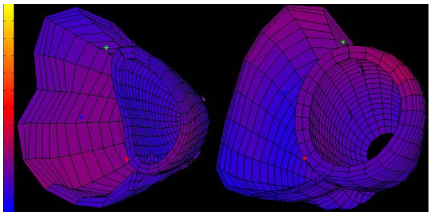

Fig. 2: Maps of minimum principal strain in a PHTN patient (left) and a normal human volunteer (right). Strains are mapped from blue = -30% to yellow = 30%.

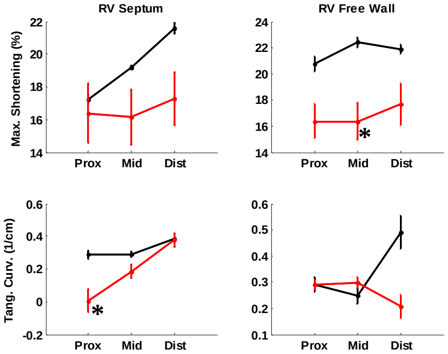

Fig. 3: Plots of systolic maximum shortening (negative of minimum principal strain) and tangential curvature both normal volunteers (black) and PHTN (red). *P<0.05 relative to normal.