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1059 Modeling interventricular septal geometry in patients with left to right shunts

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Introduction

The interventricular septum (IVS) contributes to both left and right ventricular function. The IVS is crucial to the proper functioning of the right ventricle – often the more important ventricle in patients with congenital heart disease. Consequently, assessment of the IVS shape and dynamics is a key part of assessing patients with congenital heart disease. The formalism of differential geometry is well suited for describing arbitrary parameterized planes such as the interventricular septum [1]. Using this framework allows exact mathematical description of a complex shape in terms of minimal parameters.

Purpose

The primary objective was to use differential geometry to describe quantitatively the septal geometry and its temporal evolution in patients with pre-tricuspid valve left to right shunting.

Methods

The MR images were acquired with a 1.5 T Philips system. Each of the four patients (3 PAPVR and 1 ASD, ages 11–16) and five normal subjects (ages 15–18) were referred for MR as part of a routine clinical evaluation. A SSFP sequence with parallel acquisition was used to acquire a full short axis and four chamber dataset for all subjects. Typical spatial resolution was 1.5 mm^2 with variable slice thickness of 6–8 mm. The number of cardiac phases was varied to maintain a constant temporal resolution of ~35 ms. Ventricular contours were extracted during selected phases using a previously described semi-automated boundary extraction method. The ventricular septum was manually divided from these contours from the apex to the base using both the four chamber and short axis data sets. The segmented ventricular data was transformed into a parameterized surface via an iterative regularization algorithm. The eigenvalues of the Hessian matrix describing the surface were calculated. These represent the two principal curvatures. Three geometric parameters were then derived from the principal curvatures: the Gaussian and mean curvatures, and the shape index, $2/\pi^*\tan^{-1}(\kappa2+\kappa1/\kappa2-\kappa1)$. Small regions of the septum were subjected to patch classification using a parameter space based on the Gaussian and Mean curvatures. For each of the ventricular septa, parametric maps of the maximal and minimal curvature were created at the beginning and end of both systole and diastole. The parametric maps of the patients and normals were compared qualitatively. The parameters distribution were compared quantitatively with Fisher's exact test.

Results

The parametric maps allow a qualitative assessment of the curvature for each phase of the cardiac cycle. Compared with the normal volunteers, the patients' end-diastolic parametric images showed a spatially varying mean decrease in the first principal curvature (maximal curvature). Quantitative statistical comparison of the distributions shows a highly statistically significant difference in the parameter distribution between the two groups. Interestingly, in the patients there is a spatial distribution with the base of the heart showing a significantly "flatter" distribution than the mid or apical segments. The parametric maps and quantitative distributions of curvatures are similar in both early and late systole for the patients compared with the normals. Using patch classification provides complete discrimination between the patients and normals at end-diastole, but essentially no discrimination during systole. Two of the four patients showed a significant shift to a flatter distribution at early diastole representing early diastolic equalization of right and left ventricular pressures. Both of these were associated with significantly increased right ventricular volume index.

Conclusion

Using the well developed framework of differential geometry provides an analytical method for describing the IVS. The described method easily distinguishes the septal configuration of right ventricular volume overload with flattening at end-diastole, but normal convexity at end-systole. In future work, the method will be extended to description of more complex hemodynamic lesions and patients with interventricular conduction delays.

References

1. Moses , Axel : *MRM* 2004.