O5-1

Patient-specific shape modeling to predict response to pulmonary valve replacement in patients with repaired Tetralogy of Fallot

Full P. M. (1), Engelhardt S. (2), Burkhardt B. (1), Tandon A. (1), Velasco Forte M. N. (3), Greil G. F. (1), Wolf I. (4), Lamata P. (5), Hussain T. (1)
Dept. of Pediatrics, UT Southwestern Medical Center, Dallas, US (1);Department of Simulation and Graphics, Otto-von-Guericke-University Magdeburg, Magdeburg, Germany (2);Queen Elizabeth Hospital/King's College London, London, UK (3);Institute for Medical Informatics, Department of Computer Science, Mannheim University of Applied Sciences, Mannheim, Germany (4);School of Biomedical Engineering and Imaging Sciences, King's College of London, London, UK (5)

Introduction:
Patients with repaired Tetralogy of Fallot (rTOF) may suffer from pulmonary valve regurgitation and pulmonary valve replacement (PVR) is considered in these patients. We present parameters from statistical shape model (SSM) analysis for the right ventricle (RV) to predict their response to PVR.

Methods:
Short axis cine images of 10 rTOF cases before and after PVR, and 10 healthy controls were analyzed. Manual segmentations of the RV at end diastole (ED) were performed for each patient. Three dimensional RV anatomies were automatically reconstructed from the segmentations.
SSM, also referred to as atlas, yield arbitrary many, independent modes of variation of shape by applying principal component analysis (PCA). We considered the first 3 modes covering most variance only. Adverse shape changes in rTOF patients were investigated compared to control cases. If the overall atlas (normal and rTOF cases) showed a shape difference exists between responders (RVED-Volume Index (V_i)=after PVR within normal range) and non-responders, another atlas specifically delineating shape differences within the rTOF group would be created.

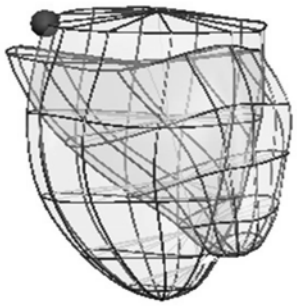

Fig.1a: Normal RV vs rTOF RV

Fig.1b: Responders RV vs non-responders RV

Figure 1: Two pairs of overlaid meshes are shown. Each pair comprises of two RV meshes and represents the change in shape for the most significant RV PCA mode to distinguish between classes of interest. The observer looks from the LV through the septum on the RV. The grey sphere represents the RVOT. All meshes are based on the shape of the RV before PVR.
Fig1a: normal hearts tend towards the gray mesh, pre PVR rTOFs tend towards the black mesh
Fig1b: pre PVR rTOF with positive response (gray) and no response (black)

Results:
The atlas built with pre-PVR rTOF ($RVEDV_i$ 154.0(+/-22.3) ml/m^2) and normal cases ($RVEDV_i$=90.7(23.3) ml/m^2) showed a significant change in size of RV(see Fig.1a, p-value<0.001), corroborated by $RVEDV_i$ (p-value<0.001). Using the same atlas but splitting rTOF cases into responders ($RVEDV_i$=148.6(+/-18.6) ml/m^2) and non-responders ($RVEDV_i$=159.4(+/-26.6) ml/m^2), we observe a significant difference in PCA mode 3 (p-vaule = 0.017), suggesting a novel shape difference exists, although there was no difference in $RVEDV_i$ between these groups (p-value=0.477). Thus this shape difference adds complementary information to the $RVEDV_i$ to predict the response to PVR in rTOF. The second atlas using rTOF cases only confirms a significant difference in RV shape (p-value = 0.015) between responders and non-responders which is manifested by a shifted position of the apex with respect to the base of the heart (see Fig.1b).

Conclusions:
In our cohort, the position of the apex relative to the base of the heart is a predictive feature for response to PVR in rTOF. Future work may confirm this and yield shape-dependent biomarkers for clinical decision-making.