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

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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 (Vi)=after PVR within normal range) and non-responders, another atlas specifically delineating shape differences within the rTOF group would be created.

Results:
The atlas built with pre-PVR rTOF (RVEDV=154.0(+/-22.3) ml/m²) and normal cases (RVEDV=90.7(23.3) ml/m²) showed a significant change in size of RV (see Fig.1a, p-value<0.001), corroborated by RVEDV (p-value<0.001). Using the same atlas but splitting rTOF cases into responders (RVEDV=148.6(+/-18.6) ml/m²) and non-responders (RVEDV=159.4(+/-26.6) ml/m²), we observe a significant difference in PCA mode 3 (p-value = 0.017), suggesting a novel shape difference exists, although there was no difference in RVEDV between these groups (p-value=0.477). Thus this shape difference adds complementary information to the RVEDV, 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.