Segmenting Heart CT Scans to Predict Clinical Results of Pulmonary Valve Replacement and Model the Development of Aneurysms

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Background

This semester's research consisted of two projects:

Segmenting CT scans of pediatric patients with defective pulmonary valves

Children with defective pulmonary valves can be treated with surgical or transcatheter pulmonary valve replacement [1]. The second option is minimally invasive but causes complications in the surrounding vessels 20% of the time [2]. To test if the transcatheter replacement will work, a balloon stent test is performed via cardiac catheterization. The Barocas Research Group aims to use patient-specific CT or MRI scans of the heart to predict the likelihood of a successful transcatheter replacement by modeling their heart anatomy and simulating the stent expansion procedure with finite element analysis. If the predictions prove to be accurate, this project could help many children avoid an invasive, expensive, and potentially unnecessary procedure!

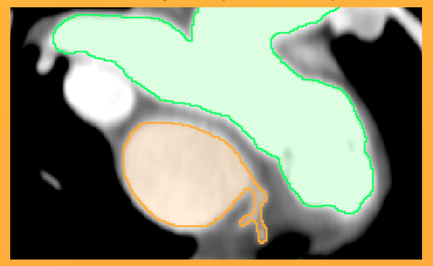
Segmenting CT scans of mice taken throughout the development of aneurysms

Aortic aneurysms can result in dissections where blood leaks between layers of the aorta and ruptures where the aorta bursts. In 2018, aortic aneurysms caused 9,923 deaths [3]. Mice models can be used to monitor the growth of aneurysms. Research about the mechanics of aneurysm development could lead to better detection and treatment in the future!

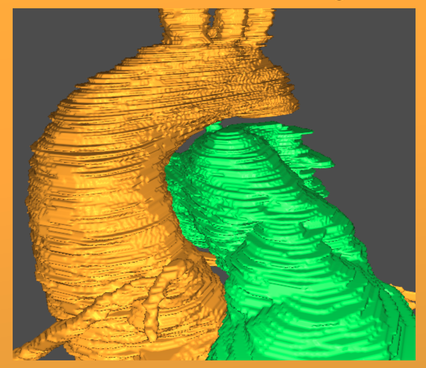
Methods

1. Gather patient-specific CT scans

2. Locate and segment the ascending aorta, left and right coronary arteries, and pulmonary artery in the area surrounding the pulmonary valve

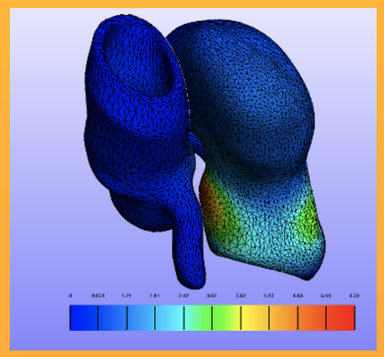


3. Create model from 2D image slices

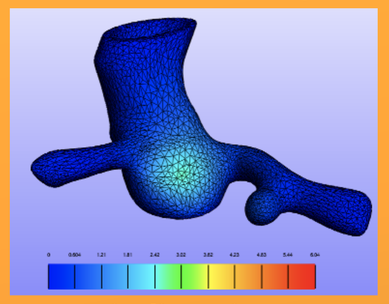


Results and Future Directions

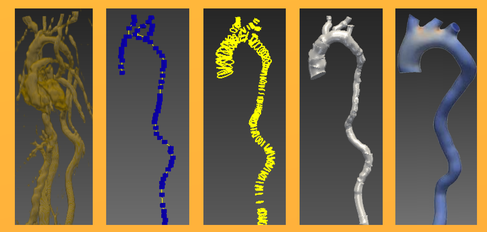
The structures I segmented are used to create patient-specific models for finite element analysis in an ongoing study. Stent expansion is simulated so the predicted aortic root distortion and coronary artery compression can be measured. Simulated predictions are compared to retrospective clinical outcomes. The finite element models that have been generated are reproductive of clinical results.



Finite element stent expansion



Aortic distortion map



1. Render volume from CT scans
2. Trace paths of aorta and arch branches
3. Segment each point along path
4. Generate 3D model from segmentation
5. Run von Mises stress distribution

The aortas of ten mice who developed aortic aneurysms are segmented at 2, 4, and 6 months. Correlations between variables including simulated blood flow dynamics from these images, individual tissue properties, and lifespans will be evaluated to potentially discover new information about aneurysm development.

Sources:

1. Zhou, Y., T. Xiong, P. Bai, C. Chu, and N. Dong. Clinical outcomes of transcatheter versus surgical pulmonary valve replacement: a meta-analysis. Journal of Thoracic Disease. 11:5343–5351, 2019.
2. Barocas, V., V. Aggarwal, and A. Qureshi. Patient specific finite element modeling to evaluate clinically relevant risks associated with percutaneous pulmonary valve replacement in children with congenital heart disease. 2020.
3. Centers for Disease Control and Prevention, National Center for Health Statistics. Underlying Cause of Death 1999–2018. http://wonder.cdc.gov/ucd-icd10.html