Artificial Cardiovascular Organ Production

Nico Marazzi
Medical Flow Physics Lab(MFPL)
Malibu High School, Class of 2024
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Introduction

In the MFPL lab researchers use In-Vitro experimental setups with fabricated components of the cardiovascular system(heart, aorta, atrium) to get physiologically relevant data without the need for invasive measurements on patients. This enables the researchers to take consistent measurements with varying conditions without the need for patients with these conditions to volunteer.

Objective & Impact of Lab's Research

MFPL research team uses experimental and clinical data to study the cardiovascular system and cardiovascular diseases. Using computational mathematics and Artificial Intelligence they create new ways for clinicians to diagnose/predict disease and other cardiovascular complications. This creates inexpensive, noninvasive, and immediate diagnosing and treatment approaches that would previously need invasive surgery.

Acknowledgements

Special thanks to Professor Niema Pahlevan for inviting me into his laboratory and allowing me to experience research. Also, thank you to my mentors: Coskun Bilgi and Soha Niroumandi for their support and training throughout this program. Final thank you to Elena Lottich for her guidance as well.

Research & Learning Process

Covered Topics

Machine Learning: We learned machine learning and data science to analyze medical data. We used TensorFlow Random Forest Regressor models and Neural Networks to develop machine learning algorithms in Python.

Aorta Fabrication

Silicone molding: Silicone to catalyst mix of 10:1. We paint on a coat of silicone then dry the mold for 12 hours at room temperature(25℃). Then we repeat this process until we have the desired thickness. For our aorta we used 3 layers.

Demolding: To remove the silicone from the mold we inject water using a syringe in between the silicone and the mold. Then we remove each branch from the mold and once every branch is removed we slide the silicone away from the main body(Candy Cane).

Branching: Then we add connectors to each branch so we can connect our aorta to the experimental set up. We connect the branches with hydrophobic sealing tape on the interior and exterior of the branch to prevent leaking and attach zip ties to secure the connectors.

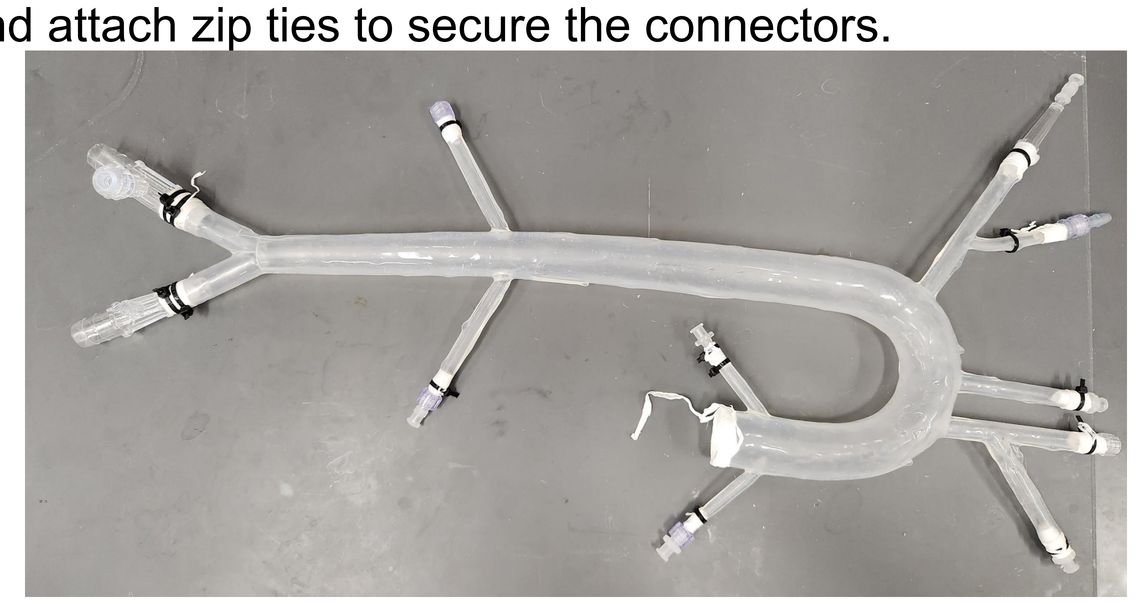


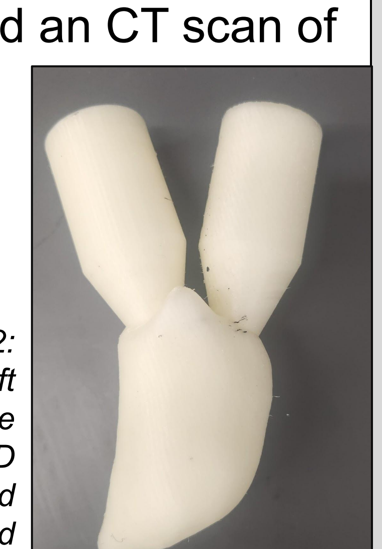
Figure 1: Silicone Aorta with connectors.

Left Ventricle(LV)

We also brushed a 3D printed LV. We used an CT scan of an LV and attached two connection points on top of the ventricle in order to seal the ventricle to our experimental set up.

Demolding:The mold is printed with a material that dissolves in water. Then the mold was cleaned and attached directly to the lab set up with sealing tape and zip ties.

Figure 2: Left Ventricle 3D printed mold



Methods & Results

Compliance Test(Δ V/ Δ P)

We run a compliance test which we can use to tell the theoretical age of our aorta. We fill the aorta with water by removing any air pockets. Then we slowly inject 5 mL of water at a time and use a pressure catheter to record the pressure at each increase in volume. The compliance is calculated by Δ V/ Δ P. The compliance of our aorta is ~1.3 ml/mmHg and when comparing this compliance to real patient data found in the graph below the theoretical age of our aorta is about 60 years old.

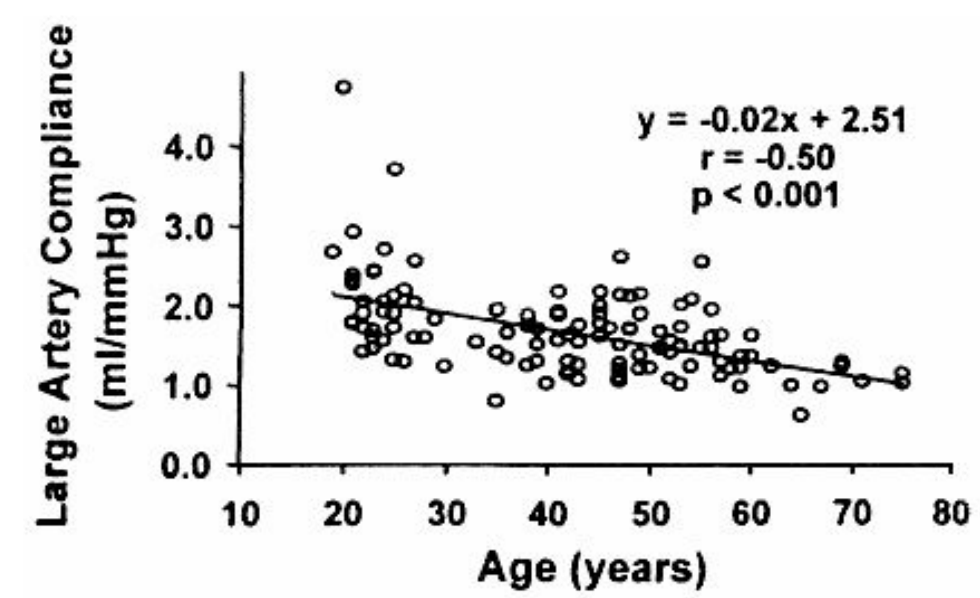
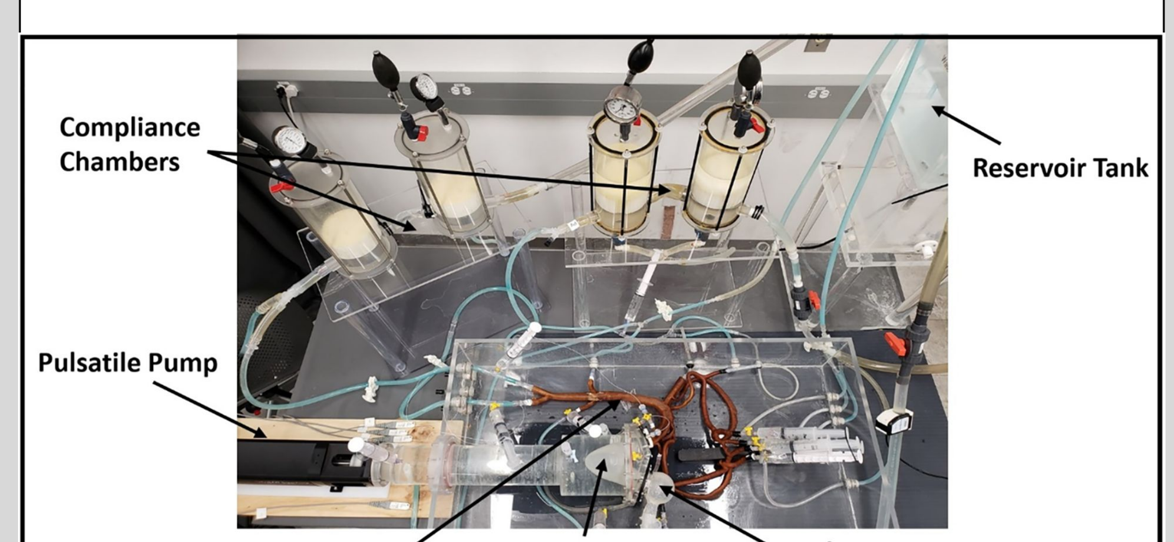


Figure 3: Graph of compliance related to age[1]

Coupling the Aorta

After running the compliance measurement and ensuring that our age is correct for the desired experiment, we then attach the aorta to the experimental setup. Using multiple catheters we can get pressure readings from different locations of the body. Then we collect waveform readings changing the cardiac output and the heart rate to observe the changes in pressure.



Waveforms

The pressure measured from the experimental setup by varying heart rate at the cardiac output of 4 L/min.

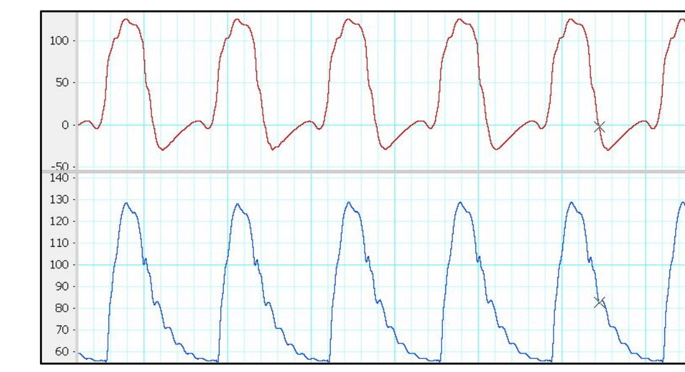


Figure 5: Waveform with a heart rate of 45 and a cardiac output of 4 L/min.

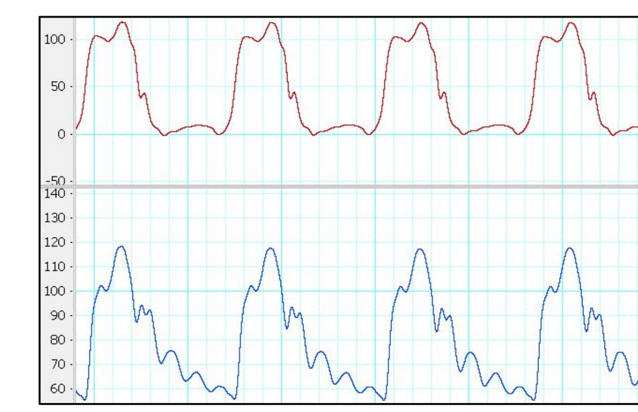


Figure 7: Waveform with a heart rate of 75 and a cardiac output of 4 L/min.

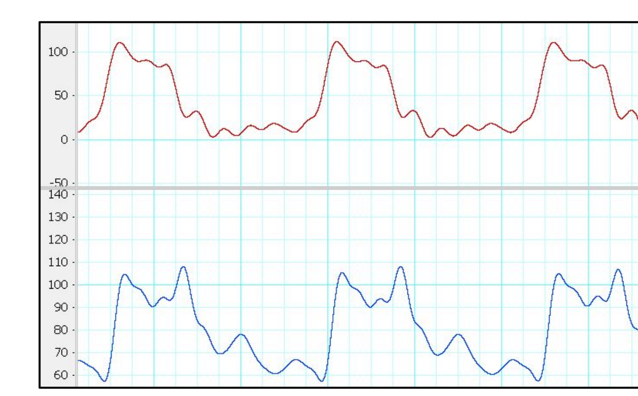


Figure 6: Waveform with a heart rate of 120 and a cardiac output of 4 L/min.

Citations

[1]G. E. McVeigh et al., "Age-Related Abnormalities in Arterial Compliance Identified by Pressure Pulse Contour Analysis: Aging and Arterial Compliance," Hypertension (Dallas, Tex. 1979), vol. 33, no. 6, pp. 1392–1398, 1999, doi: 10.1161/01.HYP.33.6.1392.

[2]Alavi R, Aghilinejad A, Wei H, Niroumandi S, Wieman S, Pahlevan NM (2022) A coupled atrioventricular-aortic setup for in-vitro hemodynamic study of the systemic circulation: Design, fabrication, and physiological relevancy. PLoS ONE 17(11): e0267765. https://doi.org/10.1371/journal.pone.0267765