Project Specifications:
Development of a Pulsatile Left Heart Simulator

Team #17
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Project for Dr. Wei Sun

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The goal of this project is to build a pulsatile flow loop that simulates and recreates the pressure and flow conditions of the left side of the heart. This loop must be able to accurately recreate the pressure and flow curves of mechanical and bioprosthetic valves that have been benchmarked in previous tests in an already existing flow loop. This project can be segmented into several key components: the atrium, the mitral valve, the left ventricle, the aortic valve, the ascending aorta, and a system of compliance chambers. The main purpose of the atrium is to act as a reservoir for the test fluid after it passes through the system. It must have a large chamber that can fluctuate in volume without causing a large increase in pressure throughout the rest of the chambers. The atrium flows next towards the mitral valve. The valve itself must be removable. This means the housing for the mitral valve (which is generally a one way bicuspid valve) must be able to fit several different types and sizes of valves. It must be able to have interchangeable segments that allow for the implantation of mechanical or bioprosthetic valves ranging from a list of sizes commonly used in medical procedures. This section must also be designed so that the mounted valve can be imaged and viewed from both sides. The fluid then runs into the ventricle.

The ventricle is the main pump for the system and should be able to integrate a pre-existing pump in Dr. Sun’s lab. The ventricle must be a rubber sack that fills with water via an intake of air on the outside of the sack that draws water into it from the atrium. When the pump expels air it should deflate the sack thereby pushing water out of it through the aortic valve. This contraction of the ventricle will in turn apply pressure to the mitral valve which should close it, preventing water from entering the atrium via this route.

This pump has a number of different settings that control the pressure going into the left ventricle. There are settings for both the diastolic and systolic pressures. The systolic pressure is the control for the contraction of the ventricle and directly influences the internal pressure in the ventricle. The diastolic pressure controls the intake of air from the ventricular chamber incasing the ventricle. This should draw out the sack filling it with a varying degree of liquid per heart beat. There is a control on the pump that regulates the beats per minute which control the number of systole/diastole cycles per minute. Additionally, there is the control for the duration of the systolic phase in milliseconds. As the liquid leaves the ventricle it must pass through the aortic valve segment. This segment will be similar to the mitral valve section but must include more variability.

In addition to being able to mount mechanical and bioprosthetic valves, this section should have a component that can be switched in and out that allows for the the implementation of a biological aortic root into the flow loop. This section should allow the root to serve as the aortic valve for the system and should function with no leaks or pressure drops. Additionally this section must also be viewable from both directions. It should have windows or ports that allow for videos to be taken of the valves in action. After passing through the aortic valve the system must have a compliance chamber which replicates the conditions that would occur if the fluid was flowing through the ascending aorta in the body. This section should include air chambers that soften the pressure curves in the loop so they more closely resemble the pressure curves found in the human body. The water collecting in the compliance chambers should then filter through a throttle valve that simulates the resistance found in the body as the blood passes through all of the arteries and veins on its way back to the heart. The fluid should then drain back into the atrium creating a contained flow loop.

Technical Specifications
One of the issues found with the existing flow loop in Dr. Sun’s lab is that when something such as an aorta is mounted into the system the compliance chambers have to be mounted several inches above where they are supposed to be. The flow from the ventricle towards the aorta is a vertical flow. Therefore when the compliance chamber is raised above where it is supposed to be, the gravity of the additional water in the system throws off the pressure curves for the system. The design of the entire system must differ from the vertical design of the previous loop and should incorporate a way to pump the fluid horizontally through the system. It should allow for something as small as a half inch tall valve to be mounted or for something as large as an aorta (varying in sizes but for example 4 inches long) to be mounted into the system. The varying sizes of valves should not alter the pressure waveforms in any sort of drastic manner for varying flows.

The loop should also be mostly made out of clear Plexiglas (it cannot contain corrodable metals inside the loop but metal may be used on parts that do not directly touch the fluids). This substance will not degrade and should allow the user to see the flow as it travels through the loop. Additionally, if possible and if time allows, there should be a way to control the temperature of the fluids traveling through the loop. This should be built into the aortic reservoir and should not impede the flow. There should also be small ports throughout the entire system at varying intervals. These should allow pressure sensors to be hooked up to them so that readings can be taken from the internal environment.

Material Specifications:

Physical:                              Plexiglas
                                           Screws, Bolts, Nuts - varying sizes
                                           6061 Aluminum
                                           Clear rubber tubing (half inch inner diameter)
                                           Liquid cement
                                           Mechanical, Bioprosthetic valves

Mechanical:                             Pulsatile airflow pump

Electrical:                             Pressure sensors
                                           Flowmeter
                                           Imaging device

Software:                               User Interfaces: Keyboard, Mouse
                                           Hardware Interfaces: DataTrax, Monitors displaying data

Safety:                                 It is important to wear gloves when handling the bioprosthetic tissue valves to avoid contamination.

Maintenance:
Due to the imperfections of the flow loop set-up, it is possible for a large amount of water to leak during the testing process. If this occurs it is necessary to clean it up completely before the next test. The water must also be emptied from the chambers and tubing in between each test run.