Project Statement:
Development of a Pulsatile Left Heart Simulator

Team #17
Stephanie Bendtsen, Joe Calderan, Celeste Dupont
Project for Dr. Wei Sun

Client Contact: Dr. Wei Sun, University of Connecticut Tissue Mechanics Lab,
260 Glenbrook Road, Unit 2247, Storrs, CT 06269, (860) 486-0369
Statement of Need

The human heart is very unique and difficult to study, so simulations are often created to model the heart and figure out exactly how it functions. The client desires a newly designed left heart simulator that functions more efficiently and allows the user to collect data more effectively. The current device is very intricate which makes it difficult to install and change the valves being tested. Once the valves have been inserted into the device, the model often does not function properly and leaks water during testing. The current device also does not allow testing with stents, which are often used in artificial heart valve replacements. By making a machine that is easier to use and functions properly, the results will be more predictable and accurate.

Introduction & Overview

The UConn Tissue Mechanics Lab is currently doing work on a pulsatile left heart simulator. This device models the heart and produces waveforms of the simulated heartbeat. Images can also be taken of some of the functioning of the heart valves during testing. This device functions as a heart in the human body would and produces generally accurate results. Since technology is becoming more advanced, this older device is being phased out and a newer, more efficient one is desired by the client.

The new device should include an easier method for mounting the aortic and mitral valves (mechanical or biological) onto the device for testing. In addition, the client wants to be able to perform tests which include engineered stents so the device should be able to accommodate this as well. One last issue with the current device is that images are not able to be taken of both the aortic and mitral valves from the top and bottom positions. The client would like the new design to include proper positioning so that images and video can be taken during testing of the device and evaluated. Since materials will act differently depending on temperature, the new device will ideally include a method for maintaining body temperature throughout the device during testing. While incorporating all of these new processes, the device must function as a heart in vivo and produce the proper cardiovascular waveforms.

Realistic Constraints

A design team must be aware of a number of constraints that exist when designing a complex project. For this design, although the Tissue Mechanics Lab has a supply of some of the materials used in the current pulsatile left heart simulator design, it will be necessary to order many parts. Since the manufacturing of each part may be costly, the budget restriction will be important to keep in mind. Also, if the UConn machine shop is unable to create a necessary part, it may require more time and money to construct it somewhere else. Because this design is very elaborate, time will be a constant constraint in both the design and manufacturing phases. Once the initial design is constructed, it is expected that troubleshooting and modifications will be necessary to achieve the appropriate cardiovascular waveform results. We may also be limited to sufficient team meetings, attributed to conflicting class schedules and laboratory availability.

More specifically, biological tissue valves may have different properties at various temperatures, so it is important that the final design closely mimics the in vivo environment. A chamber with hot water will surround the valve chamber to heat the saline solution close to body temperature.
Another complicated issue lies in the ability to obtain images of the aortic and mitral valves from both the inlet and outlet sides. The set-up may make it very difficult to obtain satisfactory images of the outlet side of the mitral valve and inlet of the aortic valve without disrupting the normal functioning as a human heart.

Other Information

ViVitro Labs Inc. in Canada has recently developed the Vivitro Pulse Duplicator, which is a pulsatile heart simulator. This device tests the performance and function of various heart valve replacements. The ViViTest software control system produces simulated cardiovascular waveforms while simultaneously collecting pressures and valve flows. Because this model allows for the testing of stented tissue valves as well as stentless valves, we may turn to this design for inspiration.

Although Dr. Sun’s current pulsatile flow loop is not as efficient as it should be, the design and cardiovascular waveforms obtained will be helpful in designing and troubleshooting the new device. While many aspects need to be altered, several of the design characteristics work well for this device and may be used as a guideline for the new device.

Questions

1. What is the exact budget?
2. How much of Dr. Sun’s existing model should we keep the same?
3. How can we alter the design to fit an aortic root into the chamber so that the waveforms produced will be close to that of a working heart?
4. If we modify the design so that the valves lie horizontal instead of vertical, will the proper waveforms be produced?
5. Should we make various valve compartments for different sized valves and valves of different materials?
6. How can we adjust the valve space in the chamber so that the tissue valves fit more properly and don’t move around?
7. What kind of biological tissue should be used to test the aortic valve?
8. What is the best material to use for each part of the system?
9. How can we improve the design to avoid leakage?
10. Can we minimize the tubing used connecting to the compliance chambers?
11. How can we set it up so that images can be taken from both sides of the valves?
12. Should we use Solidworks to construct our design or draw the setup manually?