In-Vitro Ventricular Assist Device Testing

Purpose:
- To mimic the normal systemic circulation of a young adult
- Simulate heart failure in the systemic circulation of a young adult
- To measure the effectiveness of a Ventricle Assist Device (VAD) in helping HF patients

Background:
Heart failure, a condition in which the heart can no longer pump enough blood to the rest of the body, affects 6 million people per year in the United States. Although a heart transplant is the best option, the need for donors exceeds the supply. A common alternative is the Ventricle Assist Device (VAD), which provides circulatory support for patients with HF. These devices can be used as right, left, or bi-ventricular assist pumps. To test these different devices before human trials, in the laboratory testing, also known as in-vitro testing, is needed. To get the most accurate results of device performance, a mock circulation of that closely mimics the human circulation is desired.

Method
In-Vitro Mock Circulation Setup
- Human circulation consists of multiple vessels of varying size and elasticity
- Used lumped element modeling to simplify vessel resistances and elasticity (compliances)
- Windkessel compliance chambers mimic elasticity of vessels
- Rubber tubing with clamps model vessel resistance
- To mimic the left ventricle, a Harvard Apparatus blood pump is used (pulsatile pump)

Results
Normal Mock Circulation
- In a normal mock circulation, the pressures and cardiac output are:
  - Ventricular: 0-120 mmHg
  - Atrial: 0-10 mmHg
  - Aortic: 80-120 mmHg
  - Cardiac output: 3.5 L/min

Modeling Heart Failure
- In HF, the pressures and cardiac output are:
  - Ventricular: 0-80 mmHg
  - Atrial: 10-20 mmHg
  - Aortic: 50-70 mmHg
  - Cardiac output: 2.5 L/min
- Two Tests: Unassisted and Assisted HF Model

Discussion
Normal Mock Circulation
- In the normal circulation, systolic pressure is 120 mmHg and diastolic pressure is 80 mmHg
- In this setup the aortic pressure is lower than expected
- The atrial pressure is larger than the normal range

Modeling Heart Failure
- Pressures of HF are not much different than normal circulation
- Cardiac output is lower for HF than normal circulation
- Improvement in cardiac output (flow rate) when the VAD is attached and driven in the HF mock circulation

Conclusion
The in-vitro model was in good agreement with normal human circulation. However, the HF model could be improved to better simulate systemic pressures in a patient with HF. Overall model could be improved by using viscous fluid and a constant temperature bath.

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