# MOCK FLOW LOOP (MFL) FOR SELF-POWERED FONTAN CIRCULATION

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https://sites.google.com/site/eraumebmssd1516fontanflowloop/

## BACKGROUND

Hypoplastic Left Heart Syndrome (HLHS) is a syndrome where a baby is born without a left ventricle. Survival rates are less than 50% by adulthood. A three stage surgical approach is used for treatment for the syndrome. The focus for this model is Stage III of the operation known as the Fontan procedure.

To improve the Fontan circulation, an injection jet shunt (IJS) from a single combined ventricle to the Fontan pulmonary arteries will be incorporated into the closed-loop circulation to determine if the energy and momentum will effectively be transferred to the pulmonary arteries.

## GOAL

Physically construct a dynamically scaled mock flow loop (MFL) to validate and match optimized IJS results obtained from computational fluid dynamics (CFD) design.

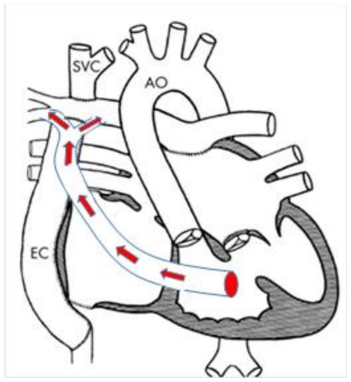


*Figure 1. Sketch of "IJS" functionality*

## METHODS

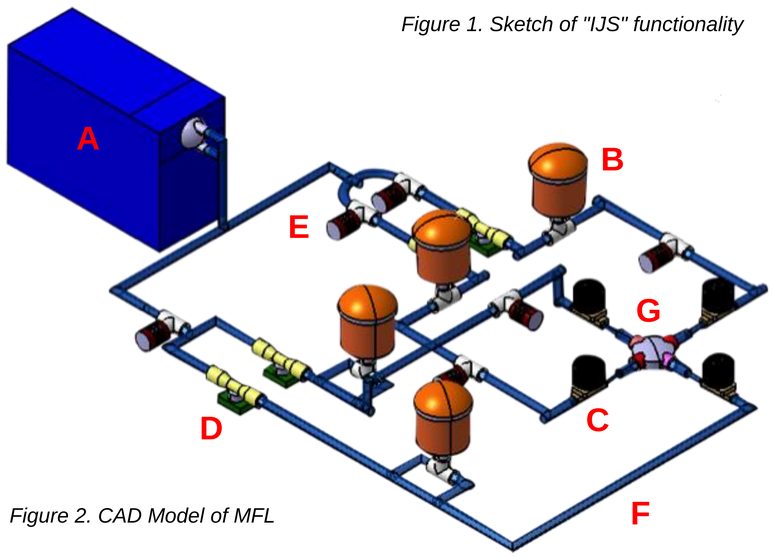


*Figure 2. CAD Model of MFL*

A. Harvard Apparatus - Heart pump to produce cardiac output
B. Compliance Chambers – Set capacitances (C)
C. Ball Valves - Control flow rate by restricting flow when needed (R)
D. Flow Meters – Acquire velocity of flow at desired location
E. Pressure Sensors – Acquire pressure of flow at desired locations
F. Tubing – Set inductances by varying length of tube (L)
G. Test junction including IJS

The Fontan procedure is the current treatment for babies born with Hypoplastic Left Heart Syndrome (HLHS). The surgery entails multiple severe complications and a survival rate of less than 50% by adulthood.

Modification to the Fontan surgery is proposed to lower mortality rate in patients. A bifurcating graft (IJS) has been designed and validated via computational fluid dynamics (CFD) to increase velocity and reduce pressure within the pulmonary arteries.

A dynamically scaled mock flow loop (MFL) will be configured to validate the optimized IJS results obtained from the CFD design. The MFL will be based on a reduced Fontan lumped-parameter model (LPM) and will be comprised of RLC componentss of the systemic and the pulmonary circuit. These RLC values are obtained from clinical references to approximate normal human physiology specific to each vessel bed.

The Harvard Medical pulsatile pump provides the targeted flow rate through the IJS. Flow and pressure sensor data at critical points in the MFL are acquired via National Instruments multichannel data acquisition board and processed using LabView. A patient-specific 3D model of the Fontan junction (test section) will be produced via 3D printing (inferior and superior vena cavae attached to left and right pulmonary arteries).

CFD results of Fontan circulation before and after addition of IJS:

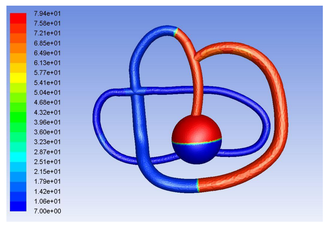

*Figure 3. Baseline Without Pressure IJS*

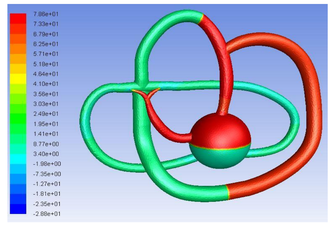

*Figure 4. Pressure Baseline With IJS*

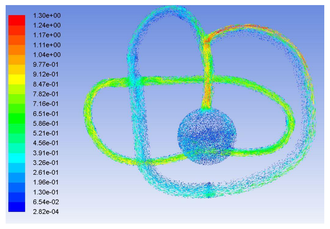

*Figure 5. Velocity Baseline Without IJS*

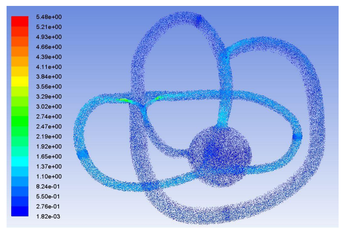

*Figure 6. Velocity Baseline With IJS*

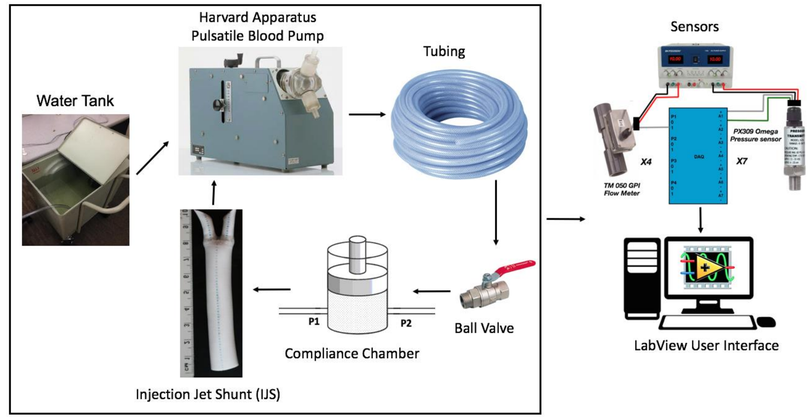


*Figure 7. Schematic of flow loop showing individual parts.*

## RESULTS

In order to develop the MFL, the design's ideal operating pressure and flow rates were derived with respect to values obtained from the numerical model of the physiological Fontan circulation.

Clinical input values were used to determine the initial parameters of the circulation system in conjunction with an experimental subject retaining the parameters of a human 6-12 month old. From this, RLC values for the clinical reference model were obtained.

| | Physiological | MFL |
|---|---|---|
| Frequency [cycles/min] | 120 | 20 |
| Divc [mm] | 13.47 | 12.5 |
| Dsvc [mm] | 13.47 | 12.5 |
| Drpa [mm] | 10.74 | 12.5 |
| Dlpa [mm] | 10.74 | 12.5 |
| Qivc [L/min] | 1.05 | 0.8572 |
| Qsvc [L/min] | 2.45 | 0.3655 |
| Qrpa [L/min] | 1.75 | 0.549 |
| Qlpa [L/min] | 1.75 | 0.549 |

*Table 1. Physiological Values vs. Mock Circulatory Flow Loop (MFL) values*

## REFERENCES

1. Veldtman, Gruschen R., and Gary D. Webb. "Improved Survival in Fontan-Associated Protein-Losing Enteropathy*." Journal of the American College of Cardiology 64.1 (2014): 63-65.
2. Quintero, Nathalie E., Closed-loop CFD Model of the Self-Powered Fontan Circulation for the Hypoplastic Left Heart Syndrome

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