Department of Biomedical Engineering
UNIVERSITY OF WISCONSIN–MADISON

Computed Tomography (CT) Circulation Phantom

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Client: Dr. Giuseppe Toia
Advisor: Dr. Chris Brace

Presentation Overview

- Problem Statement
- Background Information
- Product Design Specifications
- Preliminary Designs
- Design Matrices
- Future Work
- References and Acknowledgements

Problem Statement

- Due to the rise in respiratory and cardiovascular complications related to COVID-19, ECMO procedures have had a rise in demand
- ECMO has a 50% fatality rate, patients need CT scans for diagnosis
- ECMO can make it difficult to produce accurate CT images
- Currently, there is no definitive method of testing or calibrating CT machines for ECMO scans with the use of phantoms without spending thousands of dollars.
- Dr. Giuseppe Toia has requested a circulation system with a phantom that can aid in the calibration of CT machines for scans on ECMO patients.

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Background

- Computed Tomography (CT) - Scanning method
  - Iodinated Contrast solution
- ECMO - life support
- ECMO creates retrograde flow opposite the heart
- Blood reintroduced to body circuit after heart (femoral artery)
- Watershed areas created by ECMO and heart (aortic arch)
- Phantoms- replicate areas of body for CT calibration and testing

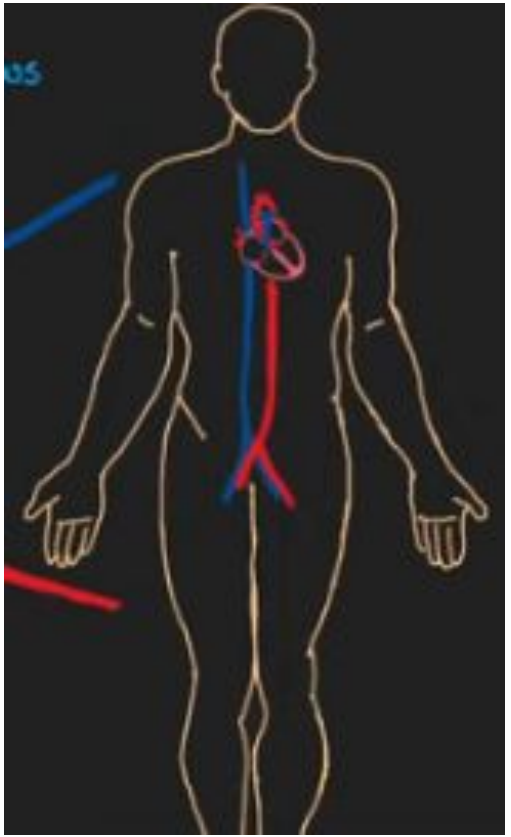


Figure 1: ECMO diagram [1]

Competing Designs

1. Gammex CTDI Phantom
   - \+ Quality Assurance Phantom
   - \- Does not address VA-ECMO situation

2. Gammex Perfusion Phantom
   - \+ Mimics injection of contrast solution in tissues
   - \- Lacks anatomical accuracy

3. Dynamic CT Perfusion Cardiac Phantom
   - \+ Studies perfusion within the heart using anthropomorphic thorax as patient simulation
   - \- Lacks anatomical accuracy (aortic valve)
   - \- Does not address VA-ECMO situation

Figure 2: Front View of Gammex CTDI Phantom [2].

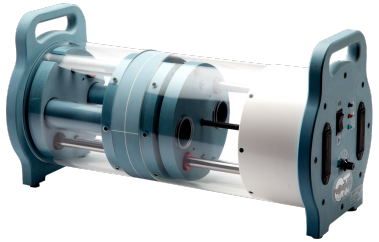


Figure 3: CT Perfusion Phantom (GammexTM Technology) [3].

Figure 4: Cardiac perfusion phantom inside the anthropomorphic thorax along with the pulsatile pump [4].

Product Design Specifications

Client Requirements

- Anatomically accurate circuit with pulsatile heart pump
- Circuit must sustain operation during retrograde flow
- Dilution Mechanism
- Integrated with previous projects
- Works to provide measurable and accurate data

Product Design Specifications

Performance

- Variable range 0 L/min - 6 L/min [1] [5]
- Output rate of 60-100 strokes/minute [6]

Accuracy and Reliability

- Must endure a fluid pressure of up to 300 mm/Hg [7]
- Dilution by reservoir
- Hold up with repeated testing

Cost

- Between $200 - $300

Materials

- Do not include metal [8]
- 3D printing filament

Elastic 50A

+ Cost-effective

+ Anatomical Accuracy

- Degradation of material with exposure to ultraviolet radiation

- May cause leaks due to the process of removing support structures

- Softer material

Figure 5: Model of heart using Elastic 50A

TPU 92A

+ Can endure CT scan environments (ultraviolet radiation)

+ Most efficient process of fabrication in terms of post-processing and support structures

+ Cost-effective

- More rigid than other materials

Figure 6: A product made from TPU 92A

Stratasys TangoPlus

Figure 7: Model of organ using Stratasys TangoPlus

+ High anatomical accuracy

+ Allows for print that causes less leaks

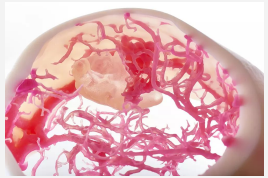
+ Quick fabrication

- Degrade with ultraviolet radiation

- Printing process/material will be outsourced

Fabrication Design Matrix

Table 1: Design matrix for the evaluation of 3 proposed materials

Design Categories (Weight)	**Design 1:** Elastic 50A 		**Design 2:** TPU 92A 		**Design 3:** Stratasys TangoPlus 	
Durability(30)	4/5	24	4/5	24	3/5	18
Reproducibility (20)	4/5	16	5/5	20	3/5	12
Supports(20)	2/5	8	5/5	20	3/5	12
Anatomical Accuracy(15)	4/5	12	3/5	9	5/5	15
Cost(15)	4/5	12	4/5	12	2/5	6
Total Points:	**72**		**85**		**63**	

BDC Laboratories PD-1100 Pulsatile Pump

Figure 8: PD-1100 Pump

- Pulsatile Pump
+ Variable flow rate
+ Measurable parameters
+ Laboratory-specific
- Low cost / availability

MicroPerpex Peristaltic Pump

Figure 9: MicroPerpex Peristaltic Pump

- Peristaltic Pump
+ Highly adjustable
+ Available in BME Teaching Lab
- Flow Rate < 1 L/min

Husky 515 Air Diaphragm Pump

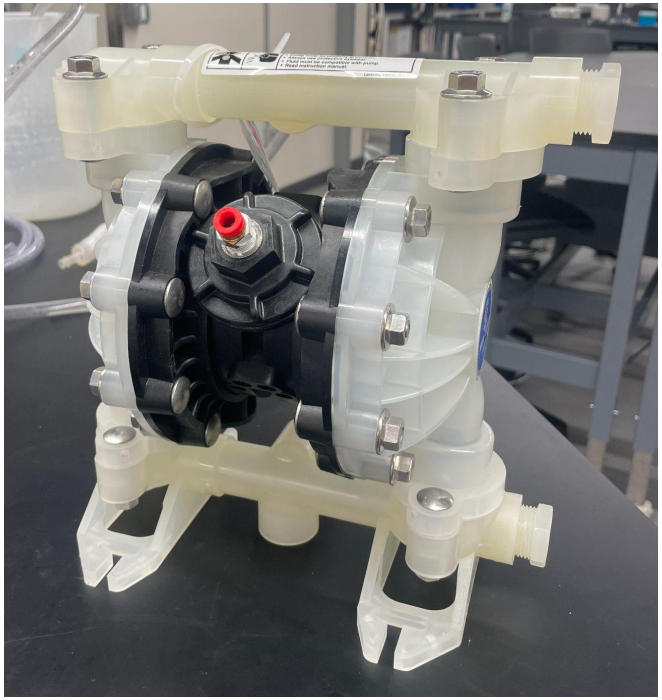


Figure 10: Husky Pump at Teaching Lab

- Air-diaphragm

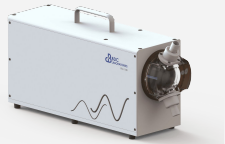
+ Variable, high output

+ Available in the BME teaching lab

- Requires an air compressor

Pump Design Matrix

Table 2: Design matrix for the evaluation of 3 proposed designs

Design Categories (Weight)	**Design 1:** LKB Microperpex Peristaltic Pump 		**Design 2:** Husky 515 Air Diaphragm Pump 		**Design 3:** PD-1100 Pulsatile Pump System 	
Flow Dynamics(30)	2/5	12	4/5	24	5/5	30
Cost/ Availability(25)	5/5	25	5/5	25	1/5	5
Ease of Use(15)	3/5	9	2/5	9	4/5	12
Weight(15)	5/5	15	4/5	12	2/5	6
Size(10)	5/5	10	4/5	8	2/5	4
Safety(5)	4/5	4	3/5	3	5/5	5
Total Points:	**75**		**82**		**61**	

Future Work

- Print aorta phantom
- Purchase pump supplies and assemble the circuit
- Prepare for CT scan
  - Leak testing
  - Output testing

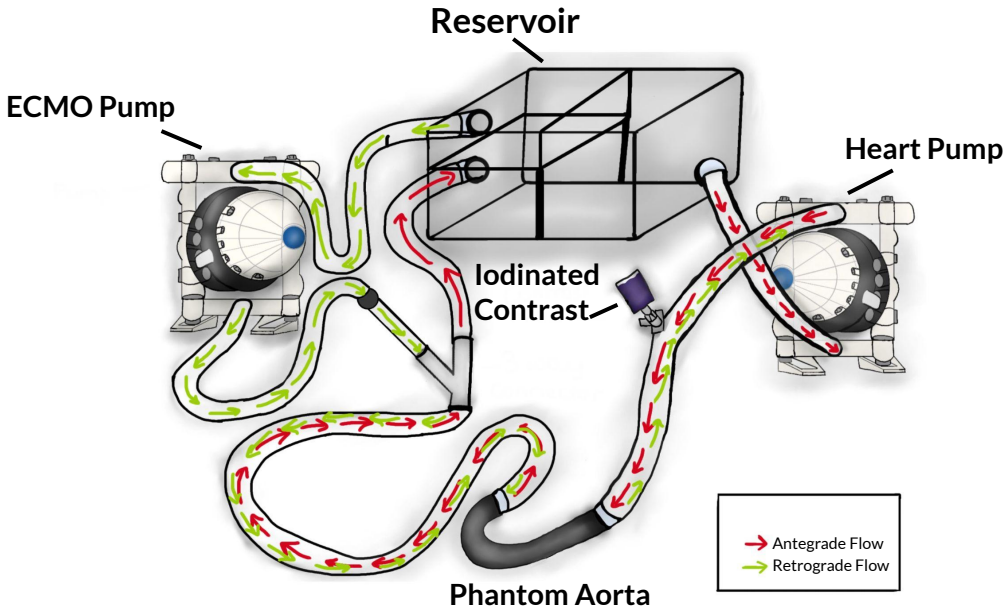


Figure 11: Sketch for full circuit

Acknowledgements

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Questions?

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