Heart Pump Modelling: Design of Pulsatile Flow Phantoms

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Introduction: The purpose of this project is to build a model, which mimics physiological conditions of the human cardiovascular system in order to simulate the parameters of the human heart in vivo. For this project, it was developed a flow phantom with vessel mimicking material, as well as blood-mimicking and tissue-mimicking fluid. Phantoms in general are specifically designed objects involving dedicated biomaterials to simulate special realistic circuits of human beings. To develop the flow phantom, low-priced biomaterials for blood mimicking fluid, tissue mimicking, and vessel mimicking material was researched. Furthermore, a proper circulation of the blood mimicking fluid and pump settings to simulate the human heart will be investigated. The development of the model will enable mimicking the blood flow in human vascular system and will guarantee quality control regarding usage of ultrasound equipment. In addition, this project will be a tool that can be used in research such as in laboratory experiments for undergraduate students.

Materials and Methods: The portable flow phantom was partly designed with Solidworks Software. It consisted of a peristaltic pump and two acrylic containers, one for mixing the blood mimicking fluid, and one for testing the ultrasound equipment. The first container had dimensions of 20 x 20 x 20 cm and was constructed using a direct current (DC) motor connected to an aluminum shaft and a 3D (three dimension) printed plastic propeller to mix the fluid. Mixing is important due to the red blood cell mimicking particle's ability to settle down at the bottom of the acrylic container. The second acrylic container had dimensions of 13 cm x 8 cm x 10 cm and had a vessel through. The tissue mimicking fluid is planned to be poured in this container so that the vessel is covered at a specific depth, measured from the top. This depth will be chosen to be to simulate the human heart muscle as good as possible. The pump mechanics explanation follows: the motor shaft and the impeller rotates, during this movement the small bearing wheels rotate toward their respectively bolts and towards the steel shaft, the small bearings also push the hose against the aluminum piece, closing the hose in contact points. This combination of movements creates a vacuum and the fluid moves in the direction of the vacuum because of the difference between pressures.

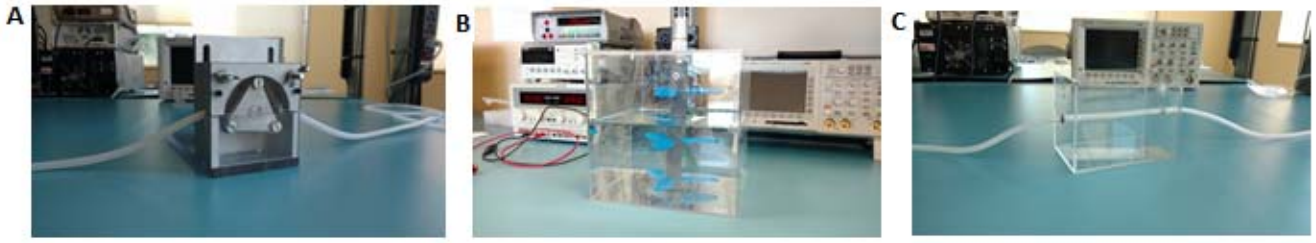

Figure 1: (A) Peristaltic pump with 4mm silicone hose (B) Mixer container (20cmx20cmx20cm) with propeller and dc motor, (C) Acrylic container (13cmx8cmx10cm)

Results and Discussion: The model was designed to enable mimicking the blood flow in human vascular system and to guarantee quality control of ultrasound equipment. Thus far, the team has constructed and tested the model as well as proposing a viable model that mimics physiological conditions of the human cardiovascular system.

Conclusions: The heart pump model was designed and built by undergraduate students from commercially available components. Futures studies may include research of biomaterials for blood mimicking fluid, data acquisition and statistical analysis.

Acknowledgements: The authors would like to thank the technical help of Jared Rees and Jacob Amos.