Design and fabrication of a soft, anatomically accurate, patient-specific cardiac simulator with sensing and controls

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Existing cardiac simulators for device evaluation are typically computer-based [1], biological [2] or mechanical [3], and have the respective inherent limitations of not allowing physical testing, difficulty in obtaining and preparing specimens, or not mimicking bulk inhomogeneous tissue material properties. We present the design, development and fabrication of an anatomically accurate, inhomogeneous, elastomeric cardiac model for *in vitro* testing of cardiac devices. Segmentation of clinical data was performed with Mimics software (Materialise). A total of twenty-one molds for chambers/vessels and structural components of the heart were designed in 3-matics (Materialise), optimized for alignment and degassing of elastomer and 3-D printed (Connex 500, Objet). Internal volumes were cast with paraffin wax. Endocardial and vessel walls and annuli were then cast in elastomeric materials that resembled material properties of corresponding native tissue. Internal volumes were subsequently melted out and elastomeric chambers and vessels were sutured together, separated by functioning valves created using an involuted tube surgical technique. These were aligned in an outer mold and a final elastomeric layer was cast to representing the myocardium. We subsequently attached this synthetic model to a commercially available pump, and modified the pump using a microcontroller to allow control of heart rate, systolic and diastolic times and incorporation of sensing capabilities (pressure and flowrate on inflow and outflow). Parameters were controlled and data was acquired and plotted via a Matlab (Mathworks, Inc.) graphical user interface. The final simulator is patient specific, easily modifiable, and has inhomogeneous material properties mimicking those of cardiac tissue. This benchtop model can be used to provide rapid meaningful data on design iterations of cardiac devices before pre-clinical testing.

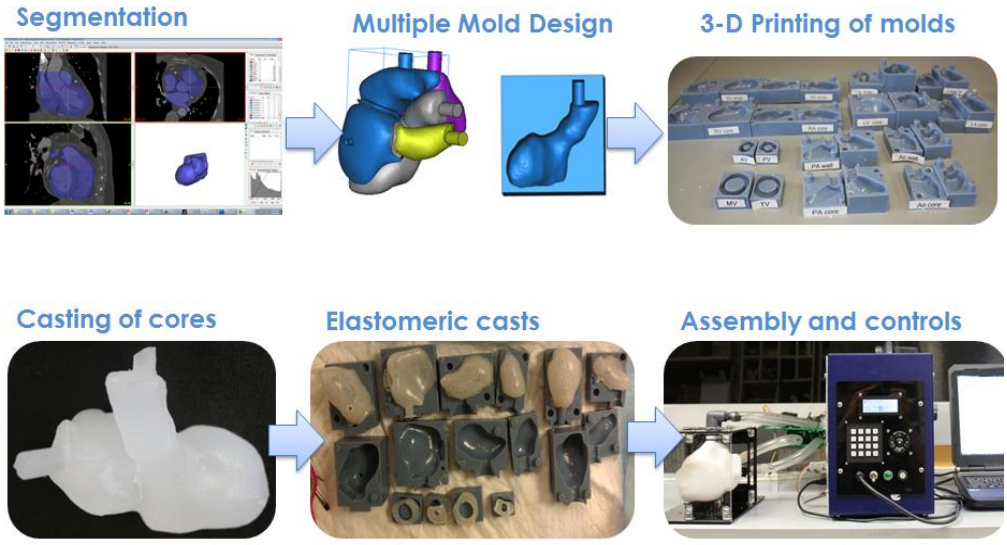

Figure 1. Workflow for the design and fabrication of the soft cardiac simulator

References

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[3] A. Alazmani, D.G. Keeling, P.G. Walker, S.K Abbas, O. Jaber, K.Watterson and M.C Levesley BioRob 2012