Development of a Pulmonary Simulator Utilizing Windkessel Modeling Techniques for Simulating Various Patient Populations within a Mock Circulatory System

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Abstract – An adaptive pulmonary simulator (PS) is essential for analyzing the possible impact of external factors on the performance, safety, and reliability of a left ventricular assist device (LVAD) within a mock circulatory system (MCS). In order to accurately and precisely reproduce the conditions within the pulmonary system, a PS should not only account for the ability of the pulmonary system to supply blood flow at specific pressures, but likewise consider the dynamics of systemic outflow. This would provide an accurate pressure and flow rate return feed back into the left ventricular portion of the MCS (i.e. the initial conditions of the left heart). Employing an embedded Windkessel model, a system model with control architecture was developed using MathWorks' Simulink® Simscape™. This model is capable of generating the left atrial pressure (LAP) waveform for given pulmonary factors, systemic variables, and aortic conditions. The adaptability of this model allows for the reproduction of a broad range of circulatory conditions (i.e. different patient populations) without the limitations of a dedicated hardware platform. The use of an embedded Windkessel section illustrates the adaptability of this approach to include a variety of circulatory model formats in the place of the chosen section. Following a verification and validation (V&V) analysis model, a PID-controlled closed-loop hydraulic system was developed utilizing Simscape™. This physical system modeling tool was used to (1) control the *in silico* system during verification studies and (2) simulate pulmonary performance for validation of this control architecture. Verification of the PS's performance and validation of this control architecture support this modeling methodology as an effective means of reproducing pulmonary pressure waveforms and systemic outflow for various patient populations.