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A Bicameral Pump for Sustained Moderate Flow Extracorporeal Circulation

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Study: The bicameral, valved Loughnane pump, US Patent 5,577,891, originally developed for use in infusion systems, was studied as an alternative to peristaltic pumps in extracorporeal perfusion systems. The pump embodies a design that allows the rebound upon emptying of one chamber to aid compression of the other chamber, reducing a principal inefficiency of peristaltic pumps. The design also reduces variations in flow associated with tube movement and fatigue in peristaltic pumps.
Methods: Here we report a preliminary engineering study intended to optimize the system for our intended application: ultrafiltration of water from blood through a small hollow fiber cartridge distal to the pump, extracting 1 ml/min from a blood flow of 35 ml/min. Tubing material and volume, operating cycle and selection of the four commercial leaflet check valves that the pump requires were evaluated in terms of long-term, unattended flow stability, power consumption, fibrin formation, and hemolysis using recalcified, outdated banked human blood.
Results: The data demonstrate feasibility of the bicameral configuration with respect to blood handling, flow stability, and reduced power consumption; a final pump design has not yet been achieved.

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Design and Development of a Hybrid Mock Circulation Loop for Hardware-in-the-loop Validation of Ventricular Assist Devices

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Study: Mock circulatory loops (MCLs) provide an in vitro benchtop test environment for evaluating ventricular assist devices (VADs). Purely hydraulic MCLs have limited control of component characteristics, especially for assessing how a VAD may operate over a broad range of patient sizes, degrees of cardiovascular disease, and activity levels. In contrast, a hybrid MCL applies pressure loading to each port of an LVAD with hydraulic conditions that are precisely controlled by a real-time computer model of the cardiovascular system (CVS) (see Figure 1). In this way, VAD performance can be assessed over a wide range of hemodynamic conditions. Further, critical cardiac events common in patients with heart failure, such as arrhythmias, can be simulated to evaluate the effectiveness and robust behavior of the VAD and its control algorithms. The model-based design and development of the hardware and software of a hybrid MCL are described, and preliminary experimental results from testing with the adult and pediatric TORVAD systems are presented.
Methods: A computational model of the human CVS is used to design and select key components of the MCL, most notably the two pressure generating interfaces (PGIs) at the VAD inflow and outflow. Simulations of the feedback-controlled PGIs in combination with a recirculating pump and a TORVAD are used to finalize the system design. Preliminary experimental testing has confirmed the pressure-tracking capability of the PGIs, which is critical for robust system performance.
Results: Simulations of the complete hybrid MCL indicate that the proposed design can track left-ventricular and aortic pressure as prescribed by the CVS model. Preliminary dynamic pressure tracking results (Figure 2) validate the design and more extensive test results with complete system will be presented.

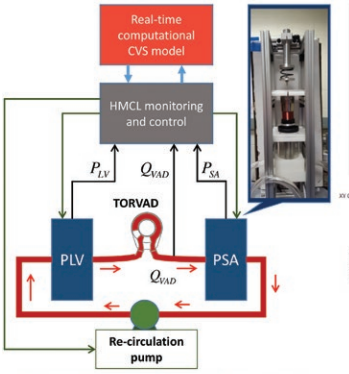

Fig 1: Hybrid MCL system schematic with insert showing prototype pressure-generating interface

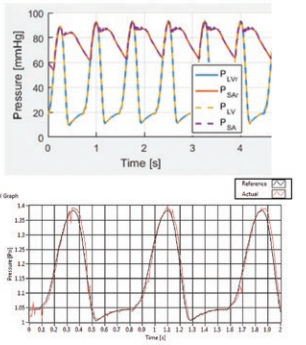

Fig 2: Tracking of left-ventricular and aortic pressure by a simulated hybrid MCL (top) and example LV pressure tracking curves in experimental testing (bottom)