

213

**Albumin Retention by an Implanted Silicon Nanopore Hemofilter**

J. J. Groszek,<sup>1</sup> C. D. Kensinger,<sup>2</sup> S. Karp,<sup>2</sup> P. Williams,<sup>2</sup> R. Kant,<sup>3</sup> T. Yeager,<sup>3</sup> D. C. Laneve,<sup>2</sup> S. Roy,<sup>3</sup> W. H. Fissell.<sup>4</sup> <sup>1</sup>Division of Nephrology and Hypertension, Vanderbilt University Medical Center, Nashville, TN; <sup>2</sup>Department of Surgery, Vanderbilt University Medical Center, Nashville, TN; <sup>3</sup>Department of Bioengineering and Therapeutic Sciences, University of California San Francisco, San Francisco, CA; <sup>4</sup>Department of Medicine and Division of Nephrology and Hypertension, Vanderbilt University Medical Center, Nashville, TN.

**Study:** We are currently developing an implantable hemofiltration device using high efficiency silicon nanopore membranes (SNMs). The goal of this study was to evaluate the albumin retention characteristics of the SNMs during short term implantation in a canine model.

**Methods:** SNMs were fabricated using previously established silicon nanofabrication techniques. SNMs were coated with polyethylene glycol to prevent biofouling. Membrane pore size and selectivity were evaluated prior to implantation by measuring hydraulic permeability and Ficoll sieving coefficient. SNMs (n=4) were housed in a custom made flow device and anastomosed to the abdominal vasculature in a canine. Systemic blood pressure provided the primary drive for filtration through the SNMs for a period of 3–4 days. Filtrate was collected from each SNM and albumin concentration was measured with an ACE Alera Chemistry System, Alfa Wassermann. Albumin sieving coefficient was taken as the ratio of filtrate albumin concentration to blood albumin concentration.

**Results:** Pre-implant hydraulic permeability of the membranes showed an average critical pore size of  $5.9 \pm 0.6$  nm; slightly smaller than the hydrodynamic diameter of albumin (7.0 nm). All four filtrate collection bags had clear effluent and showed average albumin sieving of  $0.26 \pm 0.03$ . The average albumin sieving closely matched the Ficoll sieving,  $0.27 \pm 0.06$ , at hydrodynamic diameter 4.0 nm. Though 4.0 nm Ficoll is smaller than the hydrodynamic diameter albumin (7.0 nm), it is similar to the small dimension of the ellipsoidal albumin protein (4.0 nm). These experiments demonstrate the ability for silicon nanopore membranes to retain albumin in vivo during short term implantation in a canine model. Refinement of the pore size will allow tuning of albumin retention for further testing in the in vivo model.

214

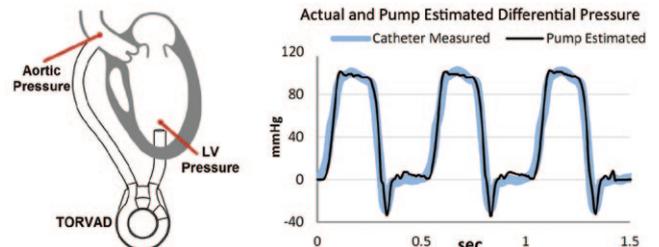
**Direct Measurement of LV-Aortic Differential Pressure Using the TORVAD Ventricular Assist Device**

R. G. Longoria,<sup>1</sup> E. R. Larson,<sup>2</sup> J. R. Gohean,<sup>2</sup> M. Kurusz,<sup>2</sup> R. W. Smalling.<sup>3</sup> <sup>1</sup>Department of Mechanical Engineering, The University of Texas at Austin, Austin, TX; <sup>2</sup>Windmill Cardiovascular Systems, Inc., Austin, TX; <sup>3</sup>Division of Cardiovascular Medicine, The University of Texas Health Science Center at Houston, Houston, TX.

**Study:** The two-piston, positive displacement pumping mechanism used in the TORVAD™ ventricular assist device is electromechanically-actuated, providing a means to infer pressure between the left ventricle (LV) and the aorta. This capability is integrated within the pump controller, providing additional insight into the state of the cardiovascular system without additional sensors. The method has been tested both *in vitro* and *in vivo*.

**Methods:** The design of the TORVAD™ relies on two pistons individually actuated and moving within a toroidal pumping chamber. One piston is temporarily held stationary to prevent flow between the inlet and outlet ports while the other is driven to eject fluid via the outlet cannula to the aorta. A static sensing mode holds both pistons momentarily thereby using the sensed motor currents to infer differential pressure across each piston. In addition to being used to estimate mean aortic and diastolic pressure, this information can also be used to aid clinicians in optimizing TORVAD™ operation. Along with other data and a computational cardiovascular system model, the differential pressure can be used to estimate important patient parameters such as systemic vascular resistance, cardiac output, and ventricular contractility.

**Results:** During acute experiments with a bovine model (n=4), testing was completed to evaluate synchronous TORVAD™ pumping. In this mode, pumping is timed based on sensed ECG signals, allowing pump ejection at different times within the cardiac cycle. During these tests, the differential pressure sensing function was used to monitor the pressure between the aorta and left ventricle. A comparison with pressure values measured using catheters (Mikro-Tip, Millar, Houston, TX) placed in the left ventricle and aorta is shown below.



Comparison between catheter measured differential pressure and value sensed by the TORVAD using current sensing during an acute animal experiment.