Hemofilter Design Based on Computational Simulations of Pulsatile Flow

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Background:

In the US, the ratio of patients with end stage renal disease (ESRD) on dialysis to annual kidney transplants for ESRD is 20:1 (USRDS 2014 Annual Data Report), underscoring the grave need for an artificial kidney alternative. Hypothesis: For the development of a hemofiltration device, computational fluid dynamics (CFD) simulations can predict potentially thrombogenic zones [e.g. low and high wall shear stress (WSS) areas, associated with stasis and shear induced cell damage, respectively] and can be used to refine device design to minimize such areas.

Methods:

CFD simulations of pulsatile blood flow through a prototype hemofilter were validated in vitro using MR velocimetry. Hemofilters were implanted in large animals (n=4) for 30 days or until thrombosis and then explanted. Based on the CFD results, a subsequent flow path was devised to minimize predicted thrombogenic regions, and simulations were conducted on the second design.

Results:

The in vitro and in silico models showed strong agreement. Pulsatile CFD simulations of the prototype device demonstrated zones of low WSS, and clot formation occurred in two of the four implants at the CFD-predicted sites. Flow simulations of the second-generation design showed reduced areas of low WSS.

Conclusions:

Thrombogenic low WSS regions predicted *in silico* correspond with clot formation in vivo. In addition to predicting areas of thrombogenicity, CFD can be used to guide hemofilter device design to minimize these sites.

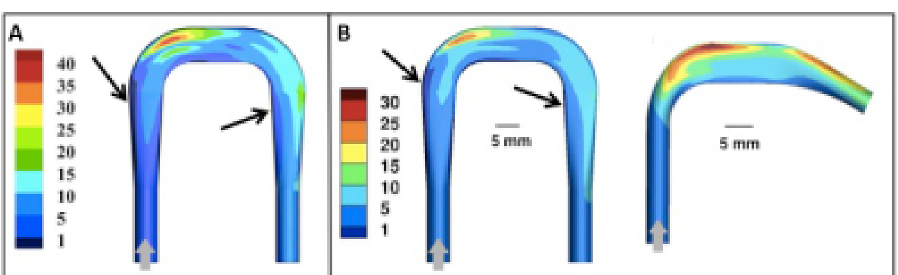

Figure 1. CFD results, with gray arrows indicating flow direction. A) WSS averaged over all but systolic acceleration for the prototype shows low WSS regions (black arrows) dominate the cardiac cycle.
B) Compared to the prototype (left), the second-generation (right) design mitigates areas of instantaneous low WSS (black arrows).