3-D CFD Optimization of a Hemodialysis Catheter

Title of Abstract (Follow First Letter Capitalization; Limit title to 100 characters including spaces.)

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Siemens PLM Authors’ names (Presenting author’s name should be underlined)

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The scientific abstract which follows should contain the same type of information as is contained in a full paper, although on a limited and condensed scale. The completed abstract should have: Title; Introduction; Materials and methods; Results; Conclusion; Disclosure statement (Conflicts of interest, real or potential perceived).

Acknowledgements and references sections are optional. The length of the actual abstract must be no more than 1 printed page and must conform to the established margins (0.75 inch margin on top, left, right, and bottom). Figures and/or tables may be embedded in relevant sections, but are included within the single page limit. Be sure that each figure/table is clearly labeled with an informative caption, and is adequately referenced within the abstract text. All sections which follow these instructions should be printed in Times New Roman, 11-point font. Section headers should appear in bold, and the text which follows in each section should be unbold.

Introduction: Catheters serve as the primary means of providing dialysis treatments to new patients as well as on a sustained basis for those who have arteriovenous damage severe enough to prevent the use of a permanent access fistula. Catheter use is, however, not without risk. They are known to be susceptible to both thrombosis, and hemolysis. Additionally, they must be shown to operate with a minimum of blood recirculation (newly dialedyzed blood being returned to the dialysis machine prior to circulating through the body). The current study uses 3-D CFD simulations to evaluate catheter performance in all three of these areas. An optimization algorithm is used to find new design concepts which will reduce the occurrence of thrombosis, hemolysis, and recirculation for the many patients dependent on catheters for their lives.

This section should include background information in order to introduce the current study, its importance to the literature, and its impact on society. The introduction should also clearly characterize the scientific question being investigated.

Materials and Methods: A parametric CAD model was developed in the Simcenter STAR-CCM+ multiphysics simulation package. It was generic in nature and does not represent any commercial catheter known to the authors but does include many of the basic design elements common in catheters today. Thirteen geometric parameters allow for a wide variety of designs. STAR-CCM+ was used to automate the meshing and CFD solution processes. Thrombosis performance was characterized as the volume percentage of separated or reversed flow in the model as these have been shown to strongly predict the incidence of catheter-induced thrombosis. An Eulerian model of hemolysis was implemented based on the work of Garon, A. which simulates the modified index of hemolysis (MIH) for each design. Recirculation was monitored via a passive numerical tracer. A hybrid-adaptive optimization algorithm SHERPA was used to solve a multi-objective optimization problem to minimize separated flow and MIH subject to the constraint that blood recirculation must be less than 0.05% by volume. The optimization was allowed to investigate 500 designs over the course of a 10 day period using 128 cores on a Linux high performance computing cluster. Materials and methods used in the study should be briefly explained in this section. For example, what patients or tissue samples were studied, what special techniques were applied and how, what devices were investigated, and what type of study was performed. When relevant, information regarding statistical comparisons should be provided. This section should also demonstrate how the methods used by the authors will address the questions presented in the introduction section. Information on the software(s)/version(s) utilized in the research is required to be entered directly via the abstract submission site at the time of submission, so this information can be considered optional in the one-page abstract itself.

Results and Discussion: This section should include a summary of any significant positive and negative results, and should be presented as concisely as possible. Most abstracts are rejected because of inadequate data. To state “results will be presented” is uninformative and of little value. Make sure any conclusions you later reach are supported by the data presented here. A sample figure has been provided below. The generic baseline simulation was shown to have thrombosis, hemolysis, and recirculation values that were generally in line with those reported for modern commercially available catheters. The best designs found over the course of the study showed...
separation values that were reduced by as much as 67% and hemolysis values that were as much as 48% relative to the baseline values. Inspection of the results identified two basic design concepts. These clusters of designs can be seen in Figure 1 below. The first group labeled “Better” retains nearly all the characteristics of the baseline with minor variations that appear to tune performance. The second group labeled “Best” was a set of unique designs which were quite different from the baseline. They were predicted to have the most improvement in both objectives.

**Figure 1.** Plot of separation (proxy for thrombosis) against MIH. The plot has been zoomed in to show the most interesting designs. The blue and green squares highlight the two principle design concepts which were found to have improved both the objectives. Feasible and infeasible indicate whether or not a given design satisfied the recirculation constraint. Be sure that the figure/table is clearly labeled, that its caption is informative, and that the data presented in the figure is referred to within the abstract text. The figure caption should be written using Times New Roman, 10 point bold font.

**Translational Impact:** Two design concepts are identified which have the potential to meaningfully reduce the incidence of thrombosis and hemolysis caused by the use of catheters for hemodialysis treatments. Conclusions should be stated concisely and should state the implications and significance of the data presented with respect to translational science. Do not introduce or defend concepts not considered in the body of the abstract. This section could also include recommendations for future studies.

**Disclosure Statement:** Any conflicts of interest associated with the study should be identified. The authors work for Siemens PLM software, the producer of Simcenter STAR-CCM+.

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