Can Superhydrophobicity Technology Reduce Blood Damage in Blood Pumps? An In Silico Evaluation

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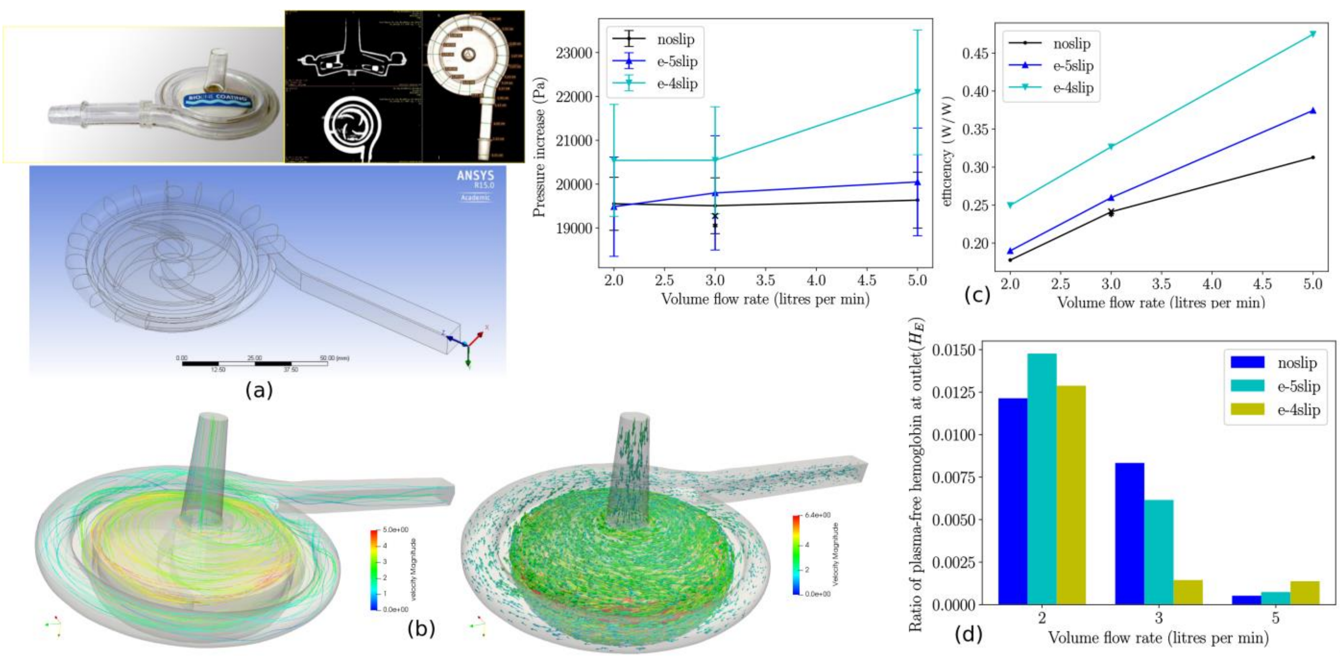
Centrifugal blood pumps are used in Extracorporeal Membrane Oxygenation (ECMO) in the ICU. High stresses imposed on blood by the rapidly rotating impeller cause clinical problems like severe hemolysis (in 7% of ECMO patients). Superhydrophobic (SHP) coatings have shown potential in reducing hemolysis. We investigated the feasibility of this solution in centrifugal blood pumps by evaluating the blood damage potential of a commercial ECMO blood pump, with and without SHP coatings. A commercial blood pump (Maquet Rotaflow) was scanned by computed tomography, the pump features as well as measurements were extracted and reconstructed. The model is simulated with CFD were performed at three flow rates: 2 LPM, 3 LPM and 5 LPM with RNG k-ε formulation to model turbulent flow in the centrifugal pump. The SHP coatings were applied only on the inner surface of the pump housing, and three levels of slip lengths were investigated: 0 μm (No slip), 10 μm and 100 μm. Results showed that applying such surface modification increases the pressure output by 5% and efficiency by 17%. These also leads to an observed significant reduction in blood damage at some flow conditions. We highlighted 3 main effects of SHP in centrifugal blood pumps which affects the resultant blood damage; (1) reduction of wall shear stresses at pump housing, (2) increased velocity fluctuations in volute and (3) reduced reversed flow in gaps. In conclusion, blood damage reduction is possible by applying superhydrophobic technology to blood pumps, but it requires further design optimizations to reduce blood damage within the entire operating range.



(a) Photo, CT scan and (c) reconstructed Maquet ROTAFLOW. (b) Stream tracer and velocity glyph results. (c) Pressure gain from the inlet to the outlet and efficiency with different slip lengths. (d) Ratio of plasma-free hemoglobin calculated with the Eulerian approach for the presence and absence of surface modifications.