A Left Ventricular Assist Device (LVAD) is a mechanical pump that provides temporary circulatory support when used as bridge to transplantation and relieves workload demand placed on a failing heart allowing for myocardia recovery when used as destination therapy. Stroke is the most devastating complication after ventricular assist device (VAD) implantation, with an incidence of 14%-47% over 3-6 months. This complication due to thrombus formation and subsequent transport through the vasculature to cerebral vessels continues to limit the widespread implementation of VAD therapy. Patient-specific computational fluid dynamics (CFD) analysis may elucidate ways to reduce this risk.

We employed a multi-scale model of the aortic circulation in order to examine the effects on flow conditions resulting from varying the VAD cannula implantation location and angle of incidence of the anastomosis to the ascending aorta based on a patient-specific geometry obtained from CT scans. The multi-scale model consists of a 0D lumped parameter model (LPM) of the circulation modeled via a 50 degree of freedom (DOF) electrical circuit analogy that includes an LVAD model coupled to a 3D computational fluid dynamics model of the circulation. An in-house adaptive Runge-Kutta method is utilized to solve the 50 DOF LPM, and the Starccm+ CFD code is utilized to solve the flowfield. This 0D-3D coupling for the flow is accomplished iteratively with the 0D LPM providing the pulsatile boundary conditions that drive the 3D CFD time-accurate computations of the flowfield. Investigated angle configurations include cannula implantations at 30°, 60° and 90° to the right lateral wall of the ascending aorta. We also considered placements of the VAD cannula along the ascending aorta in which distances of the VAD anastomosis is varied relative to the takeoff of the innominate artery. We implemented a mixed Eulerian-Lagrangian particle-tracking scheme to quantify the number of stroke-inducing particles reaching cerebral vessel outlets and included flow visualization through streamlines to identify regions of strong vorticity and flow stagnation, which can promote thrombus formation. Thrombi were modeled as spheres with perfectly elastic interactions numerically released randomly in time and space at cannula inlet plane. Based on clinical observation of the range of thrombus sizes encountered in such cases, particle diameters of 2.5mm and 3.5mm were investigated in our numerical computations. Pulsatile flow results for aforementioned angles suggest that a 90° cannula implementation causes flow impingement on the left lateral aortic wall and appears to be highly thrombogenic due to large momentum losses and zones of large re-circulation and that shallow and intermediate cannula angles promote more regular flow carrying particles towards the lower body potentially reducing stroke risk. Indications from this pulsatile numerical study suggest that up to a 50% reduction in stroke rate can be achieved with tailoring of cannula implantation. Results are consistent with significant reduction in stroke incidence achieved by tailoring cannula implantation as reported in previous steady flow computations carried out by our group. As such, results of this study suggest that a simple surgical maneuver in the process of VAD implantation may significantly improve patient life.

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The public is welcome to attend.