Numerical Model of Aortic Cannula Hemodynamics for Evaluation of Risk for Atheroembolism

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Objective: Atheroembolism from the ascending aorta is a major cause of noncardiac complications following cardiac surgery. The hemodynamics of the aortic cannula has been proven to play a significant role in atheromatous emboli generation. The design of aortic cannula is a main determinant of the flow pattern and flow velocity within the patient's aorta. The current study presents a detailed 3D numerical simulation of the flow inside the clamped aorta during cardiopulmonary bypass (CPB) and compares the flow characteristics of several cannulae designs.

Methods: Numerical models of different cannulae designs placed in a clamped aorta are presented. The models were subjected to physiological blood flow in several conditions during CBP and different cannulae orientations were examined. The numerical models were validated using in-vitro measurements of pressure drop and velocity.
Risk evaluation and hemodynamic parameters are compared, including emanating jet velocity, aortic wall reaction, emboli path lines, distribution between upper and lower vessels, risk for hemolysis, stagnation regions, and pressure drop. The simulations utilized the commercial software ADINA (ADINA R&D Inc., MA) to solve the set of fluid equations using the finite elements scheme.

Results: Cannula with straight tip generate large reaction on the aortic wall and divert more emboli from the clamp region to the descending aorta. However, cannula with sharp angled tips exhibit stronger emanating jet, higher shear stress in the cannula, more stagnant flow near the clamp region, and highly disturbed flow. Cannula with moderate angled tip demonstrate less reaction on the aortic wall and divert more emboli from the clamp region to the upper vessels.

Conclusions: The simulation results prove the significant role of cannula design and orientation in atheromatous emboli generation. The tip angle and cannula orientation in the aorta are crucial parameters in all hemodynamic aspects.