THE EFFECT OF STRUCTURE ON BLOOD PUMP HEMODYNAMICS

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INTRODUCTION

Because of the high complexity of *ventricle assist devices* (VADs) mechanisms, design considerations traditionally are based on the mechanical requirements of the energy converter and pumping mechanism. The requirements for small and light pumps with small number of moving parts are very high. Therefore, the pump blood chamber geometry is a derivative of the predefined mechanical requirements. Thus, the improvements in the chamber geometry as required by hemodynamical considerations are limited.

However, Some of the most important factors affecting longevity of VADs are their hemodynamic properties. Thrombosis is one of the primary causes of death in cardiac prosthesis patients and it could be avoided by improving the blood pump hemodynamics. Hemolysis and calcification could be reduced as well by proper design. High shear stresses, turbulence, flow separations and stagnant flow regions have to be minimized. Better understanding of the flow field inside the blood chamber and through the valves is crucial for better design of blood pumps and for long-term applications of these devices.

METHODS

The main objective of the presented study was to evaluate the effects of the blood chamber geometry and inlet operating conditions on the hemodynamic characteristics of the pulsatile VAD. For this purpose, the detailed flow dynamics inside the pulsating Berlin electrohydraulic LVAD was obtained to locate regions of high shear stress or stagnation flow. The detailed three-dimensional (3D), time-dependent (TD) flow inside different models of the blood chamber and valve types was investigated using numerical simulations.

The numerical model was validated by *in vitro* mapping of the continuous velocity field obtained from continuous digital particle-image velocimetry (CDPIV) experiments: an optically clear elastic model of the LVAD blood chamber was placed inside the CDPIV system. The CDPIV system is capable of sampling 15 velocity vector fields per second, based on image-pairs intervals lower than 0.5 millisecond..

Commercial CFD packages were used to solve the Navier-Stokes equations (CFD-RC, CFD Research Cooperation and FIDAP, Fluent Inc., Evanston).

RESULTS

The numerical and experimental results were compared for validation of the numerical model, and combined for the comprehensive description of the flow field.

Different 3D models of the blood chamber with two types of artificial heart valves were constructed and combined with various pumping conditions. Time-dependent flow simulations were performed including fluid-structure interaction calculation to obtain the motion of the chamber boundaries as a result of external pressure.

In the presentation, the global flow phenomena of the different cases will be present and the effect of pump structure and inlet conditions on the hemodynamic characteristics of blood pumps will be evaluated.

This research may offer useful information for the design or improvement of pulsating heart pumps.

SUMMARY

The combination of numerical (CFD) and experimental (CDPIV) methods resulted into the comprehensive description of the complex 3D, viscous and time-dependent flow field inside the artificial ventricle. After the validation of the numerical model, the detailed numerical simulation were very useful providing valuable information that was hard or even impossible to obtained experimentally such as shear stresses or 3-D flow.

The valve type and chamber structure had a strong effect on the flow inside the chamber, as well as the pumping and inflow conditions. The simulation of the membranes motion was essential for demonstrating the exact flow behavior during systole.

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