Abstract

Heart diseases, among non-communicable diseases, are the leading cause of death globally. Heart transplantation (HT) is a gold standard treatment for end-stage heart failure (HF), however, acute scarcity of donor organs miserably fails to meet the demand. Therefore, mechanical circulatory support (MCS) has gained popularity as an alternative treatment method. Left ventricular assist device (LVAD) and other MCS have been used for bridge-to-recovery and bridge-to-transplant therapies. The current MCS research is focused on its use as destination therapy. Although LVAD technology has evolved significantly, limitations such as post-implant complications, low quality of life, and affordability are prevalent. A comprehensive LVAD development approach has been discussed in this study which aims to address some of the relevant issues.

A detailed numerical simulation has been adopted for the initial phase of the development. Different geometric configurations for the impeller have been examined. Based on the simulation outcomes, the most suitable configuration was chosen for the impeller. The final design was studied for different operating conditions. Also, to include the effects of different blood rheology, Newtonian as well as non-Newtonian models have been considered for this study.

The design finalized through simulation has been tested in experimental trials. Prototypes have been fabricated using a numerically controlled metal-cutting process. The pump prototype was tested in a test loop where the head and flow rate were evaluated at different impeller speeds. Additionally, the pump was tested in a mock circulation loop, constructed to mimic the physiology of the cardiovascular system. A reasonable compensation for reduced aortic pressure has been obtained using the developed LVAD.

Finally, a numerical simulation was carried out to study the effect of internal thrombus formation on the pump performance. It has been seen from estimated results that the presence of clots inside the pump reduces its pumping ability. Also, the effect of growing clot size has been studied and results have been presented in terms of changes in pressure head, shear stress, and efficiency.

This study provides insights into developing a centrifugal LVAD through numerical simulations and experimental testing. It also highlights changes in blood flow dynamics inside the pump in the presence of clots.

Keywords: Heart Failure, Mechanical Circulatory Support, Left Ventricular Assist Device, Computational Fluid Dynamics, Centrifugal Pump, Wall Shear Stress