ABSTRACT

Cardiovascular diseases are considered to be the main cause of death in developed countries. Due to limitations resulting from in-vivo measurements of velocity, the analysis and evaluation of hemodynamic parameters by means of computational simulations have become the only efficient solution, especially in cases of pathological ventricle or of assisted conditions. A Left Ventricle Assist Device (LVAD) has been used to provide hemodynamic support to patients with critical cardiac failure. The approach used in this work is to develop a Computational Fluid Dynamics (CFD) model of the aorta, including a mechanical support similar to the LVAD (Jarvik 2000 Heart Inc, New York, NY) in order to assess its effects on local haemodynamics. Its purpose is to analyse the hemodynamic effects of a continuous flow LVAD, evaluated in three different working conditions, taking into account the outflow-graft anastomosis in two different locations: thoracic and ascending aorta.

Keywords:  Aortic Flow, Assist Device, Cardiovascular Modeling, Computational Fluid Dynamics (CFD), Left Ventricle, Left Ventricle Assist Device (LVAD)

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INTRODUCTION

Cardiac failure has been defined as the epidemy of third millenium. The high number of patients requiring heart transplant for end stage cardiac failure shows that replacement therapy is not a real option for all patients. Therefore, mechanical assistance is becoming a valid option to bridge patients to cardiac transplantation and to a destination therapy. A LVAD is a life saving tool used when the natural heart is unable to provide sufficient blood flow. This device is a compact pump which is helpful for both bridge to transplantation and permanent mechanical circulatory support. An implantable LVAD has to be small and efficient, generating $5 \text{l min}^{-1}$ blood flow rate. Since the instrumentation for flow measurements is extremely difficult became necessary to analyze the haemodynamic behaviour by using computational techniques.

The LVAD produces two different haemodynamics effects:

- Causes a end-diastolic pressure decreasing in the left atrium
- The systemic flow rate increases and, as a consequence, the systemic venous return and the right ventricle preload increase as well.

In 2002, Dr Westaby and colleagues (Westaby et al., 2002) implanted axial flow pump from the apex of the left ventricle to the descending aorta (Jarvik Heart Inc., New York). Low incidence of postoperative complications and totally implanted system allowed an increasing number of patients treated with Jarvik Heart. Jarvik devices an axial pump implanted inside the left ventricle with transapical approach and having as an outflow to descending aorta, through a left thoracotomy. This pump is surgically connected to the heart and the aorta in order to increase systemic blood flow. Therefore, LVAD is able to generate up to five liters of flow from a totally implantable system allowing a better quality of life. Another technique consists in ascending aorta anastomosis, as in the HeartMate models, through a midline sternotomy. Some of them reached follow-up above five years from the implantation. However, the main question in patients of Jarvik Heart is represented by the flow pattern to the brain with a source of retrograde flow.

Some concerns has still raised with retrograde blood flow, in descending aorta suture, especially about by type of flow to the TSA vessels in different conditions of cardiac output.

Clinical experience demonstrated more probability of cerebral washout in surgeries characterized by retrograde perfusion than in anterograde flow (Svensson et al., 2004). Conversely, following fifty years and thousands of patients perfused retrogradelly to femoral approach, no major adverse effect caused by pattern flow was reported. In addition, in ascending aortic aneryisms operations occurred same morbility with ascending aorta or femoral arterial cannulation (Lakew et al., 2005). Finally, in patients with retrograde flow from apico–aortic conduits with two decades of follow-up and more, no adverse effects were observed with retrograde flow (Renzulli 2000). However, in the last case, the aortic valve couldn’t be closed.

On the other hand, CBP studies (Pekkan et al., 2008) considered the turbulences caused by the inflow cannula in ascending aorta. The jet, hitting anterior wall of the descending aorta, moved to epiaortic vessels through a tortuous pathway, that increased wall shear stress and blood damage.

Computational flow study of hemodynamic problems is extremely challenging, and the potential advantage of computational tools for improving health care is huge. More Computational Fluid Dynamics (CFD) studies how mechanical hearts, heart valves or assist devices have been performed in the last years. CFD is a valid alternative to experimental methods because it can produce flow field data in great detail. Thus, the analysis of hemodynamic parameters by means of numerical simulation becomes the unique and efficient solution. Different models (0D, 1D, CFD, FSI) have been developed in recent decades in a variety of applications (study of hemodynamics in specific vascular districts in physiological conditions...
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