A Left Ventricular Assist Device (LVAD) is a mechanical pump that helps patients with heart failure condition. This rotary pump works in parallel to the ailing heart and provides an alternative path for blood flow from the weak left ventricle to the aorta. The LVAD is controlled by the supplied pump motor power. An increase in the pump motor power is followed by an increase in the pump speed and the pump flow, and vice versa. The LVAD is typically controlled with fixed setting for the pump power. This basically means that the controller does not react to any changes due to variations in the activity level of the patient. An important engineering challenge is to develop a feedback controller for the LVAD that can automatically adjust the supplied pump motor power so that the resulting pump flow matches the physiological demand of the patient. The availability of a mathematical model that can accurately simulate the interaction between the cardiovascular system of the patient and the LVAD is essential for the advancement in the controller development. The use of such models helps engineers and physicians in testing their theories, assessing the effectiveness of treatments, and understanding in more details the characteristics of this coupled bio-mechanical system.

The first contribution of this research is the development of a pump power-based model for the cardiovascular-LVAD system. Previously, the mathematical model in literature assumed the availability of the pump speed as the independent control variable. In reality, however, the device is controlled by pump motor power which, in turn, produced the rotational pump speed. The nonlinear relationship between the power and the speed is derived and interesting observations in the pump speed signal are documented.

The second contribution is the development of a feedback controller for patients with an LVAD used as a destination therapy or bridge to transplant device (i.e. the LVAD is implanted to support the patient permanently with no plans for device removal). The main objective chosen for this controller is to provide a physiological demand of the patient equivalent of that of a healthy individual. Since the device is implanted for a long period of time, this objective is chosen to allow the patient to lead a life as close to normal as possible.

The third contribution is an analysis of the aortic valve dynamics during support with the LVAD. The aortic valve experiences permanent closure when the LVAD pump power is increased. The permanent closure of the aortic valve can be very harmful to the patients using the device as bridge to recovery treatments. The analysis shows the various changes in the hemodynamic variables of the patient as a result of aortic valve closing. The results show the relationship of the activity level and the heart failure severity to the duration of the aortic valve opening.

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Approved for distribution by Marwan Simaan, Committee Chair, on September 29, 2014.

The public is welcome to attend.