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Preload-based Starling-like control of rotary blood pumps: An in-vitro evaluation (Article)

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Abstract

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Due to a shortage of donor hearts, rotary left ventricular assist devices (LVADs) are used to provide mechanical circulatory support. To address the preload insensitivity of the constant speed controller (CSC) used in conventional LVADs, we developed a preload-based Starling- like controller (SLC). The SLC emulates the Starling law of the heart to maintain mean pump flow (Q_P) with respect to mean left ventricular end diastolic pressure (PLVEDm) as the feedback signal. The SLC and CSC were compared using a mock circulation loop to assess their capacity to increase cardiac output during mild exercise while avoiding ventricular suction (marked by a negative PLVEDm) and maintaining circulatory stability during blood loss and severe reductions in left ventricular contractility (LVC). The root mean squared hemodynamic deviation (RMSHD) metric was used to assess the clinical acceptability of each controller based on pre-defined hemodynamic limits. We also compared the in-silico results from our previously published paper with our in-vitro outcomes. In the exercise simulation, the SLC increased Q_P by 37%, compared to only 17% with the CSC. During blood loss, the SLC maintained a better safety margin against left ventricular suction with PLVEDm of 2.7 mmHg compared to -0.1 mmHg for CSC. A transition to reduced LVC resulted in decreased mean arterial pressure (MAP) and Q_P with CSC, whilst the SLC maintained MAP and Q_P. The results were associated with a much lower RMSHD value with SLC (70.3%) compared to CSC (225.5%), demonstrating improved capacity of the SLC to compensate for the varying cardiac demand during profound circulatory changes. In-vitro and in-silico results demonstrated similar trends to the simulated changes in patient state however the magnitude of hemodynamic changes were different, thus justifying the progression to in-vitro evaluation.

Indexed keywords

EMTREE medical terms: Article bleeding blood pump cardiovascular equipment cardiovascular parameters coronary artery blood flow disease severity exercise intensity feedback system heart hemodynamics heart left ventricle contractility heart left ventricle enddiastolic pressure heart output heart preload in vitro study left ventricular assist device mean arterial pressure myocardial disease outcome assessment preload-based Starling-like controller simulation computer simulation equipment design evaluation study exercise heart assist device heart left ventricle function hemodynamics human physiology