SYSTEM LEVEL ANALYSIS OF VENTRICLE ASSIST DEVICES FOR RIGHT VENTRICLE FAILURE

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Introduction

Discussing heart failure, the left ventricle (LV) is mainly considered, and the right ventricle (RV) is overlooked. However, the function of this "forgotten ventricle" also plays a crucial role in several disease conditions. These RV failure states are commonly treated via commercially available ventricle assist devices (VADs). Even so, as a major limitation, these VADs are suitable for systemic support with higher pressure and resistance, thus, utilization of LVADs in pulmonary circulation may lead to unphysiological hemodynamics and suction in RV. Therefore, in this study, we aim to *in silico* investigate commercially available LVADs in RV support and then optimize these devices to be more suitable for pulmonary circulation via target hemodynamics. Our previously developed adult lumped parameter model network [1] was modified to simulate four most common RV failure cases: *(1)* pulmonary thromboembolism, *(2)* isolated RV infarction, *(3)* RV failure secondary to LV failure and *(4)* RV failure after LVAD implantation. Heartmate 3 (HM3) was characterized and used as the commercial VAD in this study.

Methods

Euler turbomachinery equation, including friction losses, was used for VAD characterization as follows:

$$Q = \frac{\rho w^2(\sigma {r_2}^2 - {r_1}^2) - \Delta P_{th} - \Delta P_{loss}}{\frac{\rho w r_2 cot\beta_2}{2\pi r_2 b_2 - tzb_2} - \frac{\rho w r_1 cot\beta_1}{2\pi r_1 b_1 - tzb_1}} \quad (1)$$

where Q is the pump flow rate, ΔP_{th} and ΔP_{loss} are the theoretical pump pressure and losses, respectively. Indices 1 and 2 represent the inlet and outlet of the associated design parameter as shown in Table 1, with the values used for HM3. ΔP_{loss} is the total friction loss of impeller, diffuser, volute and inlet and outlet tubing.

Parameter	HM3
Blade angle – β (1-2)	24° – 35°
Impeller radius – r (1-2)	3.2 – 9.6 mm
Blade width – b	4.6 mm
Blade thickness – t	3 mm
Blade number – z	4

Table 1: Inlet (1) and outlet (2) design parameters.

Disease cases were generated via modifying our previously developed healthy adult model's [1] compliances, systemic/pulmonary vascular resistances, and heart rate. In this abstract, results for pump implanted acute state of disease cases *(1)* and *(2)* are demonstrated. Disease cases *(3)* and *(4)* results will be presented during the meeting. Furthermore, chronic state of each disease case is generated via considering cardiovascular system's physiological response to RV failure through a novel optimization-based remodeling framework that aims to conserve the *key health indicator (KHI)* of cardiovascular circulation.

Results

Table 2 shows the *in silico* HM3 implanted (RV to pulmonary artery, rotational speed = 4000 rpm) acute states of disease case *(1)* and disease case *(2)*.

	Healthy	(1)	(2)	(1)+ HM3	(2)+ HM3
P_{AO}	133/66	84/57	83/57	105/70	106/71
P_{RV}	25/7	58/10	42/10	42/13	35/8
P_{PA}	25/10.5	57/14	45/15	85/17	77/15
CI	3.64	1.8	1.8	2.45	2.5
P_{RA}	5.5	15	15	13	13

Table 2: P_{AO}: aortic pressure, P_{RV}: RV pressure, P_{PA}: pulmonary pressure, P_{RA}: right atrial pressure. All pressures are in mmHg. CI: cardiac index (l/min/m^2)

Discussion

Our results showed that a commercially available pump utilization in RV support improves hemodynamics in acute state as expected, despite undesired pulmonary pressure increase. Via tracking the KHI, change in this key hemodynamics will better reflect to generate chronic RV failure state and a more suitable VAD for right side can be designed through hemodynamic target-based optimization of parameters in Table 1. Therefore, our tool numerically investigates the RV failure for the first time in literature as our knowledge, has a potential to contribute to the emergence of more physiological and suitable for right site support devices. These system level studies are crucial towards achieving a dedicated RV support device with optimal physiological response.

References

1. Sisli et al, Ann Biomed Eng, 12: 2853-2872, 2023.

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