HEMOCOMPATIBILITY OF ROTODYNAMIC BLOOD PUMPS UNDER REALISTIC OPERATION CONDITIONS

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Introduction

The operating conditions of rotodynamic blood pumps significantly influence in-vitro hemocompatibility of blood pumps in terms of the normalized index of hemolysis (NIH). Elevated NIH was observed at lower pump flow rates and higher pump speeds [1]. However, these in-vitro investigations were restricted to static pump flow conditions. Realistic pulsatile conditions in patients which may lead to periodic low flows or even flow reversal during the diastolic phase and high flows during the systolic phase of the cardiac cycle were not reflected in these in vitro setups [2]. The aim of this study was to determine hemolytic effects of realistic pulsatile operating conditions within the HeartMate 3 (HM3, Abbott Inc, Chicago, USA).

Methods

Pulsatile blood experiments were performed in a hybrid mock circulatory loop (HMCL) with citrated human blood from hemochromatosis patients. Briefly, the HMCL applies realistic simulated pressure waveforms to a running pump via a pneumatic-hydraulic interface [3]. For two pump speed settings (typical: 5600rpm and off-design: 4800rpm) with targeted mean flow rates of 4.3L/min and 2.5L/min, respectively, three different conditions were investigated: high pulsatile, low pulsatile and constant flow. Experiments were conducted for 12 hours with a change in operating condition every 4 hours. Delta free hemoglobin ($dfHb_{30min}$) and NIH were assessed every 30 minutes. In addition, blood cell counts were evaluated every hour.

Results

Six experiments were performed for each pump speed setting. The mean flow rate and pulsatile flow ranges are presented in Table 1. There was no significant difference of $dfHb_{30min}$ and NIH for the three conditions in both typical as well as off-design pump speed setting (Table 1). However, between the two pump speed settings, the differences in $dfHb_{30min}$ reached statistical significance (0.49±0.20 vs 0.69±0.24 mg/dL, p=0.01), with a trend towards higher NIH for the off-design pump setting (2.81±1.08 vs 2.19±0.72). Blood cell count remained stable over the course of the experiments.

Discussion

This study investigated the effects of pulsatile operating conditions on hemolysis at different pump speeds. The results demonstrated that at the same speed and same mean flow rate, the amplitude of flow pulsatility did not affect $dfHb_{30min}$ and NIH. Even periodic occurrences of low flow rates/flow reversals during diastole (with high statically determined NIH values) in the off-design condition did not significantly impact hemolysis. This finding can be explained by the fact that $dfHb_{30min}$ at each speed setting does not considerably change with flow rate, and NIH is calculated as the ratio between $dfHb_{30min}$ and mean flow rate, leading to similar results, almost independently from flow pulsatility.

A comparison of $dfHb_{30min}$ and NIH values for the two different pump speed settings revealed a significant difference in $dfHb_{30min}$ (higher in the typical speed setting) and NIH (higher in the off-design speed setting, which can be explained by the effect of different pump speeds ($dfHb_{30min}$) and residence times at lower flows (NIH). Further assessment for microparticles, vWf cleavage, and platelet activation is required to elucidate the impact of periodic pulsatile flow conditions on blood trauma and thrombogenicity.

		Constant flow	Low pulsatile flow	High pulsatile flow
Typical pump setting 5600rpm	Mean flow (L/min)	4.27 ± 0.03	4.27 ± 0.03	4.29 ± 0.04
	Pulsatility range (L/min)	-	3.75±0.03 - 5.03±0.03	2.68±0.15 - 6.57±0.31
	NIH (mg/100L)	2.35 ± 0.89	1.81 ± 0.51	2.40 ± 0.67
Off-designed pump setting 4800rpm	Mean flow (L/min)	2.38 ± 0.07	2.38 ± 0.02	2.51 ± 0.13
	Pulsatility range (L/min)	-	0.96±0.04 - 4.37±0.07	-0.38±0.17 - 6.61±0.17
	NIH (mg/100L)	2.65 ± 2.03	2.55 ± 0.34	2.74 ± 1.61

Table 1: Mean flow rate and pulsatile flow range for three conditions of each pump setting together with the calculated NIH value (expressed as mean ± SD).

References

1. Escher et al, IEEE Trans Biomed Eng, 69(8): 2423-2432, 2022.
2. Belkin et al, J Card Fail, 28(5): 845-862, 2022.
3. Bender et al, IEEE Trans Biomed Eng, Dec 22;PP, 2023.

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