DESIGN AND IN VITRO TESTING OF A VALVELESS UNDULATING DISPLACEMENT PUMP FOR EXTRACORPORAL MEMBRANE OXYGENATION

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Introduction

Extracorporeal membrane oxygenation (ECMO) temporarily supports critically ill patients with cardiopulmonary support. Commonly used centrifugal pumps in ECMO systems pump blood at high pressures of up to 700 mmHg and flow rates that can fall below 1 l/min. Depending on the patient's needs, there is a wide range of operating points regarding head pressure and flow, which are often far outside the optimized design point of the pumps, increasing the risk for adverse events.[1]

Positive displacement pumps may offer an alternative, as their flow rates are more independent of the head pressure and mostly determined by the stroke volume times the pumping rate.

In this study, we propose a valveless, undulating displacement pumping concept with an adjustable pump gap and stroke volume that is operated by kinematic driven by a standard rotary motor. The concept might offer a blood gentle pumping principle over a broad operation range.

Methods

Stereolithography (SLA) 3D Printed parts were used as flow guiding and structural mechanical components. A kinematic, including two spherical polymer friction bearings and a ball cup friction bearing, was designed to transform the rotary motion of the motor into the undulating motion needed for the proposed pumping principle. A polyurethane foil of 200 µm thickness was thermoformed to serve as a pump sealing between the pump housing and the moving pumping part, designed to be stretched only to a minimal extend.

Pumping tests were performed with water-glycerol mixture (60/40 wt.) as blood mimicking fluid. Head pressures and flow rates were recorded for different pumping rates and pump adjustments.

Results

The kinematic allowed an adjustable undulating amplitude and pumping gap, leading to stroke volumes between 20 and 25 ml. Depending on the stroke rate, the set pumping rate and the set pumping gap, flow rates of up to 3.8 L/min against head pressures of up to 210 mmHg could be reached, ultimately leading to bending of some structural components.

Discussion

The tested undulating pump allows pumping of blood mimicking fluid with moderate flow rates of 3.8 L/min and head pressures of up to 210 mmHg after the positive displacement pump principle, without the need of valves or a driving membrane. The pumping limits were rather reached because of structural weaknesses of some kinematic parts as well as imperfect tolerances due to 3D printing, than by the underlying pumping principle.

The shape of the thermoformed polyurethane foil is concepted to meet a compromise between manufacturability, mountability, washout, back flow and minimized foil stretching, but should be optimized for a fixed stroke volume.

This initially realized pump has rather generic dimensions and motion profiles since this is the very first realization effort. However, it shows promising results that indicate an early proof of concept of the pumping principle.

Therefore, a redesign of the pump is currently conducted, including stronger structural parts of the kinematic, attuned pump dimensions and pump rates as well as optimized foil shape.

With this, the overall hemocompatibility of the pump concerning blood damage and the risk of thrombus formation, especially over a broad range of operation points, needs to be assessed in future studies.

References

1. Gross-Hardt, Sascha et al. "Low-flow assessment of current ECMO/ECCO2R rotary blood pumps and the potential effect on hemocompatibility." Critical care (London, England) vol. 23,1 348. 6 Nov. 2019, doi:10.1186/s13054-019-2622-3