DEVELOPMENT OF AN ISOLATED HEART AS PHYSIOLOGICAL BLOOD PUMP FOR HEMOLGICAL INVESTIGATIONS IN ARITFICAL LUNGS

Giuliano Giacoppo (1, 2), Lars Krenkel (1, 2)

1. OTH Regensburg, Department of Biofluid Mechanics, Regensburg, Germany

2. Regensburg Center of Biomedical Engineering, OTH and University Regensburg, Germany

Introduction

Acute or chronic diseases as Chronic Obstructive Pulmonary Diseases (COPD) or Acute Respiratory Distress Syndrome (ARDS) adversely affect lung functionality or can even result in total lung failure. With an artificial lung (extracorporeal membrane oxygenation - ECMO), the physiological function can be supported or completely taken over. However, complications can occur such as blood coagulation, destruction of red blood cells (hemolysis) or internal bleeding. [1]
For better understanding of the complications in ECMO, an innovative test bench (Fig. 1) has been developed, inspired by the ex-vivo platform of J. de Hart [2]. An isolated, perfused porcine heart, which serves as a physiological blood pump, is adapted according to the concepts of Langendorff [3] & Neely [4]. Therefore, the bench replaces the conventionally used mechanical pump as it might induce potential hemological complications. This will enable the differentiation of fluid-mechanical processes, biocompatibility problems, and pump-related phenomena.

Methods

Porcine hearts (Fig. 2) were used as they are available in large quantities in slaughterhouses. Since these are anatomically and physiologically similar to human hearts [5], these represent good experimental alternatives.
In order to prepare the hearts for the experiments, they were harvested and treated immediately after slaughtering according to the current guidelines for transplantable hearts [6]. The coronary arteries were carefully prepared at the base and separated from the aorta. The open vascular outlets (ostia) were sutured utilizing the left side of the heart as a pump for a separate, independent test circuit. The coronary arteries are short-circuited to the right side of the heart via an extracorporeal membrane oxygenator (as lung replacement) supplying 37°C tempered and oxygenated blood. As soon as the heart was brought to a physiological temperature, the myocardial muscle began to contract autonomously, initiated by the heart's own excitation system, the sinus node.

Results

About six hearts have already been successfully resuscitated which contracted continuously for longer time. However, most hearts showed strong bleeding effects at the myocardium after approx. 15 min as well as a derailment of important blood parameters (e.g. pH value, electrolyte balance) which led to cardiac arrest. The desired pumping performance duration of eight hours could not be achieved yet.

Discussion

It has been shown that the probability of success, using an isolated heart as a physiological pump can be considerably increased by shortening the warm ischemia time. Therefore, a very short warm-up phase of the heart to body temperature during reperfusion is required. It is imperative to keep the perfusion blood at constant physiological parameters. Of high importance are the pH value, the temperature, the electrolyte balance and the oxygen or carbon dioxide partial pressure. Overall, these factors make the handling of the test bench highly sensitive and smallest deviations can lead to the failure of the experiment.
In order to achieve the desired pumping performance duration of eight hours, current processes, as well as the monitoring and adjustment of the blood parameters, will be optimized. For this purpose, “Flow-through Cells” (FTC) sensors which enable monitoring the blood parameters will be implemented. With help of gathering physiological data, a regulation for essential parameters (e.g. ph value) can be integrated.

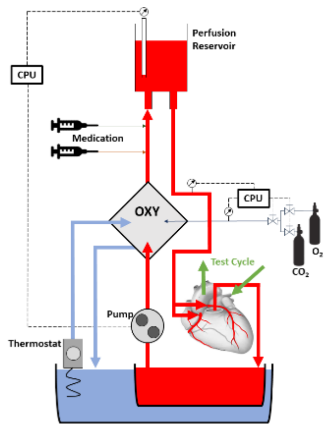

Figure 1: Schematic test bench for the isolated perfused heart.

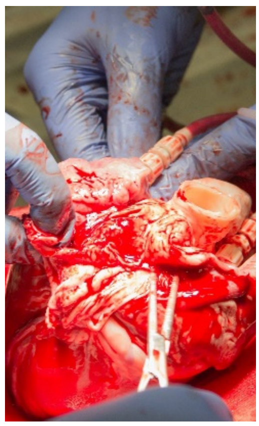

Figure 2: Connection of coronary arteries for reperfusion.

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