SIZE OF CANNULAE FOR EXTRACORPOREAL CO2 REMOVAL THERAPIES

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Abstract

Extracorporeal CO_2 removal devices ($ECCO_2R$) can be used in clinics to decarboxylate blood externally for patients suffering from pulmonary insufficiencies like acute respiratory distress syndrome. In this work, we propose a model of the respiratory system coupled with such a device to analyze the decrease of CO_2 partial pressure in the blood as a function of the blood flow through the device. Thanks to this information, the size of the cannulae can be optimized.

Keyword(s): biomechanics

1. INTRODUCTION

Acute respiratory distress syndrome (ARDS) is still life threatening despite new strategies in mechanical ventilations. Usually patients are ventilated with low tidal volume, low airway pressure and high content in O_2. Such ventilation can induce a hypercapnic acidosis, which is very deleterious for the global physiology. Consequently, extracorporeal CO_2 removal devices ($ECCO_2R$) are used to control the CO_2 partial pressure (pCO_2) in blood. In order to minimize the invasiveness of the technique, a mathematical model of the respiratory system and the $ECCO_2R$ was developed to find the appropriated blood flow through the device. With this information, the invasiveness can be minimized by optimizing the size of cannulae.

2. METHODS

We derive a simple model from the works of Batzel *et al*. [1]. This model takes into account a pulmonary shunt and the $ECCO_2R$ consists in adding a second "lung compartment", which is perfused by a fraction of the systemic blood flow extracted in the inferior vena cava and reinjected in the atrium, after crossing the device [2].

The validity of the model was tested on pigs, with the approval of the Ethics Committee of the Medical Faculty of the University of Liège [3].

For a given flow (chosen thanks to the mathematical model), the size of cannulae influences the pressure drop and the shears stress. To avoid blood damages, the inlet pressure before the pump has to be larger than -50 mmHg. The limitation of positive pressure is less severe; the outlet pressure after the pump has to be smaller than 300 mmHg [4].

3. RESULTS AND DISCUSSION

The results of our model are presented in Fig. 1, which shows the decrease of pCO_2 in terms of the flow crossing the $ECCO_2R$. As expected, the decrease is faster for large values of the flow. A blood flow around 0.5 l/min seems to be a good compromise between fast decrease of pCO_2 and limited flow in the device. For this flow, a pediatric Bio-Medicus femoral venous cannula with a diameter of 10 Fr gives a pressure drop of -18 mmHg and a pediatric Bio-Medi femoral arterial cannula with a diameter of 8 Fr gives a drop pressure of 57 mmHg [5]. These cannulae minimize the invasiveness and respect the limitations to avoid blood damages.

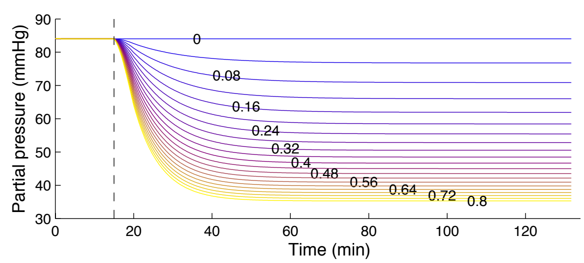

Figure 1. pCO_2 decrease over time. Labels on the curves give the blood flow (l/min) through $ECCO_2R$, which is switched on at *t =15 min*.

References

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