

PFC Treatment Unit of the liquid ventilator Inolivent-8 for total liquid ventilation of extreme prematurity ovine models

Mouhamed Amin Boudaouara¹, Philippe Micheau¹, Sébastien Poncet¹, Christophe Morin², Étienne Fortin-Pellerin²

¹CRASH-UdeS, Mechanical Engineering Department, Université de Sherbrooke, Sherbrooke, QC, Canada

²CHUS, Department of Pediatrics, Université de Sherbrooke, Sherbrooke, QC, Canada

*Philippe.micheau@usherbrooke.ca

ABSTRACT

As active care to babies born at 22 weeks of gestation is becoming a reality in Canada. Invasive mechanical ventilation is always required for the survival. The lack of surfactant in their lungs makes it difficult to fill them with air. On the other hand, in total liquid ventilation (TLV), the lungs are filled with a breathable perfluorocarbon liquid (PFC) while the liquid ventilator forces the PFC in and out of the lungs with a pumping system. For this purpose, the research group Inolivent has developed a liquid ventilator, Inolivent-8, composed of 3 units. The control unit controls the ventilator and interacts with the clinician via a graphical user interface. The PFC circulation unit (PCU) is the pumping system using two piston-syringe pumps and four pinch-valves. The PFC treatment unit (PTU) dilutes an air/oxygen bubble mixture in the PFC, removes CO₂, and regulates the temperature of PFC.

During 6 hours of experiments of TLV with an ovine model of extreme prematurity (1.5 kg), Inolivent-8 was driven in order to maintain the lungs filled with PFC (30 ml/kg) and to renew a tidal volume of PFC (20 ml/kg) at a given respiratory rate (5 cycles/min). The PTU was tuned to deliver a PFC fully saturated in oxygen during the beginning of the TLV. However, the lead time between the adjustment of the air/oxygen mixture and the repercussions on the subject affected the clinician's ability to avoid the administration of too much oxygen. The objective of this study is to model and characterize the PTU performances in order to improve it.

The analytical model of the O₂ concentration in the PFC circulating in the PTU is a first order model characterized by a time constant (τ) and a time-delay (R). Experimental methodology consisted of separating the PTU from Inolivent-8, looped it with a recirculating pump at 3 L/min and changed the air/oxygen bubble mixture from 21% to 100%. The O₂ concentration level in the PFC was measured with a dedicated sensor and recorder for post-treatment. The identified time constant was $\tau = 4$ min meaning that it takes 12 minutes of the PFC concentration to be at +/-5% of the O₂ concentration mixture.

A new TLV prototype of liquid Ventilator is being developed to ventilate small animals (500 g). Among other refinements, the fast tuning of the oxygen concentration in the inspired PFC will be addressed during the design process.