MATHEMATICAL MODELING OF EXTRACORPOREAL CO2 REMOVAL

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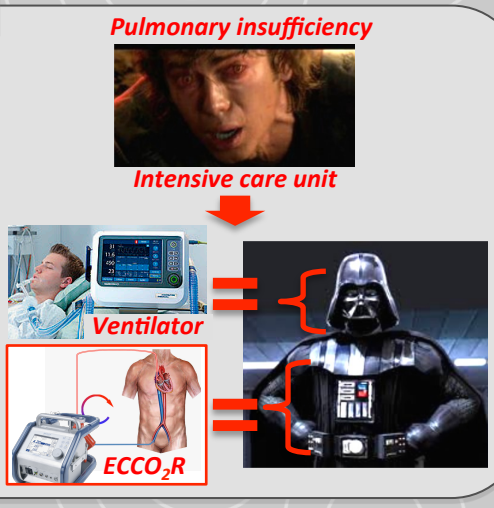
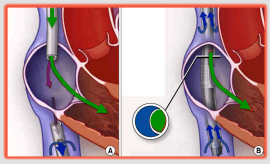
Introduction

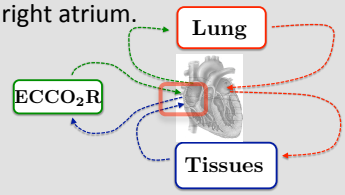
- Extracorporeal life support (ECLS) and ventilator are crucial for helping people with severe pulmonary diseases in intensive care unit
- Protective ventilation (low tidal volume) induce high CO_2 partial pressure (pCO_2) and severe blood acidosis (pH < 7.3)
- An extracorporeal CO_2 removal device ($ECCO_2R$) is a veno-venous ECLS which is used mainly to decarboxylate blood.
- A mathematical model of the cardio-pulmonary system assisted by an $ECCO_2R$ was developed with the long term purpose of optimizing the use of this device.
- After a validation of the model, the coupled system was studied in terms of blood flow crossing the medical device.
- The **higher the flow** in the device, the **faster the decrease in pCO_2**
- But blood flow has to be low to use **small cannulas** (decrease the risk of hemorrhage and infections).



Methods

- A simple model derived from the work of Batzel et al. [1] was built for which a pulmonary shunt is taken into account in parallel to the lung.
- The $ECCO_2R$ is modeled like a second "lung compartment" [2] which is perfused by a fraction of the systemic blood flow extracted in the inferior vena cava and reinjected in the right atrium.





- The validity of the model was tested by comparing its predictions with experimental data.
- The experiments were carried out on pigs, with the approval of the Ethics Committee of the Medical Faculty of the University of Liège.

Results

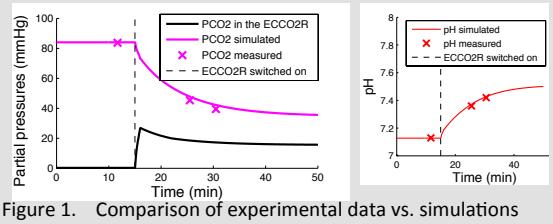


Figure 1. Comparison of experimental data vs. simulations (blood flow across the medical device = 0.6 l/min and cardiac blood flow = 4l/min)

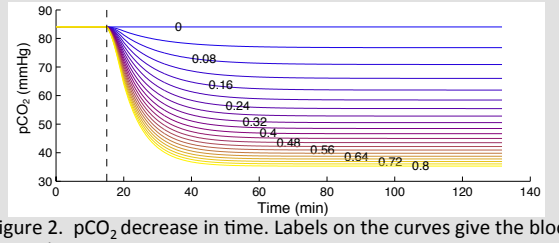


Figure 2. pCO_2 decrease in time. Labels on the curves give the blood flow (l/min) through $ECCO_2R$. The device is switched on at *t =15 min*. Cardiac blood flow for this simulation = 4l/min

Discussion

- Figure 1 shows the good agreement between the experimental and calculated time evolution of pCO_2 and pH in arteries.
- Figure 2 shows that the decrease is faster for large values of the flow across the device.
- 0.6 l/min seems to be a good compromise.
- Our calculations can thus be considered as a first step towards an **optimized clinical use of $ECCO_2R$.**

References

1. Batzel et al. Cardiovascular and respiratory systems: modeling, analysis, and control, *SIAM,* 2007.
2. Berno J E Misgeld. Automatic control of the heart-lung machine. *Ruhr-Universität Bochum, Diss,* 2006

Acknowledgments

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