Extension of CO_2-Guided Physiological Closed-Loop Control by Safety Measures in Mechanical Ventilation of Neonates

(Master thesis)

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Motivation

This work is part of the NANNI project, which is researching advanced methods for the ventilation of neonates.

Artificial respiration of newborns is a life-saving measure, which is associated with severe risks for the patient's health at the same time. If ventilation parameters move outside the physiological range, damage can be caused to the lungs, the brain and other internal organs. This trade-off between maintaining adequate gas exchange and preventing the patient from harm by the artificial respiration itself, requires the ventilation settings to be constantly monitored and adjusted. Today, this complex and time-consuming task is performed by physicians. Automatizing this process offers the perspective of improving patient care and relieving medical staff. To apply such automation, safety measures to protect patients from harm are of great importance.

State of the Art

A physiological closed-loop control algorithm to adjust parameters in ventilation of neonates by guidance of arterial partial pressure of carbon dioxide ($PaCO_2$) has been proposed in an earlier thesis.

The basic idea of safety measures in this context is to incorporate medical expert knowledge into the control algorithm. In neonatal closed-loop control of oxygenation, guided by blood O_2-saturation, this is widely done in form of rule-based algorithms. Also, optimal targeting schemes are used, e.g., the minimization of the work of breathing. A commercially available ventilation mode utilizing especially this technique is INTELLiVENT®-ASV® by Hamilton Medical AG, which is mainly used for adult treatment. Further, model-based approaches are under current research.

Objective

The aim of this work is to extend the previously developed algorithm by safety measures, to protect the patient's lung tissue and allow consideration of spontaneous breathing efforts of the patient. The extended control algorithm shall be evaluated in an animal model. For this purpose, a suitable setup is to be developed, including real-time communication between the controller and the ventilator, as well as a graphical user interface (GUI) to control the experiments.

Proposed Procedure

Suitable methods to protect the lung tissue will be researched by literature and adapted to the application in neonates. To enable consideration of spontaneous breathing, a breath detection algorithm developed in an earlier thesis will be used. Both will be developed and integrated with the existing control in MATLAB SIMULINK. The GUI will be implemented in C++ using the Qt framework. The whole development process will be based on appropriate methods of risk management according to DIN EN ISO 14971 and usability engineering according to DIN EN IEC 62366-1.

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