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Adaptive control system for volume-controlled ventilation in small animals

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Introduction

During mechanical ventilation in small animals a discrepancy between tidal volume applied through a piston ventilator and the measured volume displacement of the thorax occurs. Such differences, which can be as large as (10-30 %) depend on the mechanical properties of the lungs and thorax, as well as the volume and resistance of the tubing system. In this study we evaluate an adaptive controller developed to guarantee application of desired tidal volumes during variable volume-controlled ventilation.

Methods

A small animal study workplace (target system) consisting of a Harvard Apparatus Inspira ASVp piston ventilator and a whole body plethysmography chamber was used to ventilate and measure tidal volume, respectively, in anaesthetized rats. An adaptive control algorithm was developed and implemented based on the least-mean-squares algorithm. The controller adaption step factor α was derived using k past cycle values of set tidal volume at the ventilator (VT_{set}), desired tidal volume (VT_{des}) their differences (dVT) as well as the airway pressure amplitude (amPaw) measured at the opening of the endotracheal tubus. The performance of the controller in terms of transition time, stability and robustness was evaluated in numerical simulations and was validated in a series of physical test lung experiments.

Results

During numerical simulations and test lung experiments the controller reached a range in dVT of less than 5 % of desired VT independent of the volume-control mode (constant or variable tidal volume control) in less than 60 cycles. Furthermore the controller showed robust performance for up to three consecutive cycles of VT measurement corruptions. An optimal number of past cycles considered for controller adaption was found to be k=30.

Conclusion

The adaptive control system developed allows delivery of tidal volumes fulfilling accuracy requirements for mechanical ventilation of small animals, and may therefore prove useful in laboratory practice.

Word count:

Introduction	76
Methods	120
Results	69
Conclusion	27
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