Towards modelling of patient-ventilator interactions using model based methods

TOWARDS MODELLING OF PATIENT-VENTILATOR INTERACTIONS USING MODEL-BASED METHODS

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1. INTRODUCTION

Mechanical ventilation is an important life-saving intervention on the ICU. Lung-protective ventilation techniques such as pressure support ventilation (PSV) are used frequently in the ICU. However, asynchronies, poor patient-ventilator interactions during PSV, are shown to be harmful and are linked with increased lung injury and mortality [1]. There is a need for automatic detection and classification of asynchronies for clinical studies, algorithm development and for real time clinical decision support for smart ventilation technologies. So far, reasonable results of detection of asynchronies have been obtained, but classification is still a challenge. In this work, we generate training and classification waveforms for our machine learning study using a patient-ventilator simulation model. From these models the flow, pressure and volume waveforms can be created for different types of parameter settings. Note that the type of asynchrony and timing of the patient effort are known.

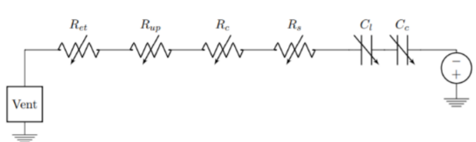

Figure 1 Example of one of the lumped-element models, with airway resistance, visco-elastic properties of the lung, and the muscles of the patient. Details of the ventilator model are not shown.

2. MATERIALS AND METHODS

For the patient-ventilator simulations, we used lumped-element models, which were already used before to model the human respiratory system [2]. The advantage is that existing electronic circuit simulators can be used, and that the circuits are easy to extend. It is possible to include the most relevant features of the respiratory system and ventilators. For our first simulations we applied the model and the parameter values used in [2], and implemented it in LT Spice XVII. An example of our lumped-element models is shown in Figure 1. It is important to include turbulence in large diameter tubes, collapse of bronchi and lung volume dependence in the smaller airway resistances and to use non-linear volume-pressure relations of the lung and chest wall.

3. RESULTS AND DISCUSSION

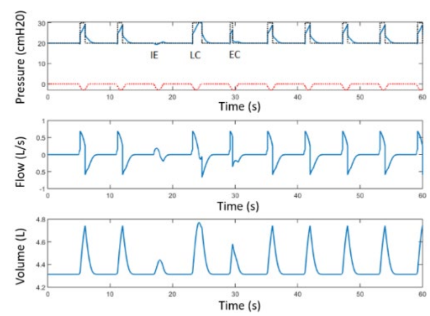

Figure 2 Example of simulated waveforms, including three types of asynchronies; early cycling, late cycling and ineffective effort for a patient model at high PEEP.

In Figure 2 we show the output pressure, volume and flow waveforms generated by the model in Figure 1. We also show three types of asynchronies, the features in the waveforms agree well with measured data. With the model in Figure 1 a dataset will be generated, for further training and improvements of our existing asynchronies classification algorithm. In future work these models can then be adapted to include the interaction between the ventilator and the patient with lungs affected with diseases.

References

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