ISB 2015

Respiratory

ISB 2015-235

MODELLING EXPIRATION USING VISCOELASTIC PRESSURE DEPENDANT RECRUITMENT MODELS – IS IT THE SAME AS INSPIRATION

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Preferred Presentation: Oral Presentation
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Clinical Biomechanics Award: No
David Winter Young Investigator Awards: No
Emerging Scientific Award sponsored by Professor J De Luca: No
Promising Scientist Award sponsored by Motion Analysis: No

Introduction and Objectives: Viscoelastic Pressure Dependent Recruitment Model (VEPRM) models recruitment, over-distension and viscoelastic effects under various ventilation manoeuvres [1]. This model improves understanding of respiratory pathophysiology in complex lung diseases such as Acute Respiratory Distress Syndrome (ARDS) and allows accurate model predictions of patient response to differing ventilator settings which can be used in a clinical setting to improve patient care.

Methods: VEPRM [1] is based on the pressure recruitment model which uses the alveolar recruitment mechanism proposed by Hickling [2], where viscoelastic effects are assigned to each layer of the recruitment model. This results in pressure dependant compliance and resistance. Passive expiration can be modelled by the analysis of the VEPRM with a reverse in the direction of the flow, and the addition of an expiratory resistance, which represents the resistance to expiration due to the ventilator tubing. Expiratory resistance can be estimated by simple linear regression of the airway pressure and flow [3].

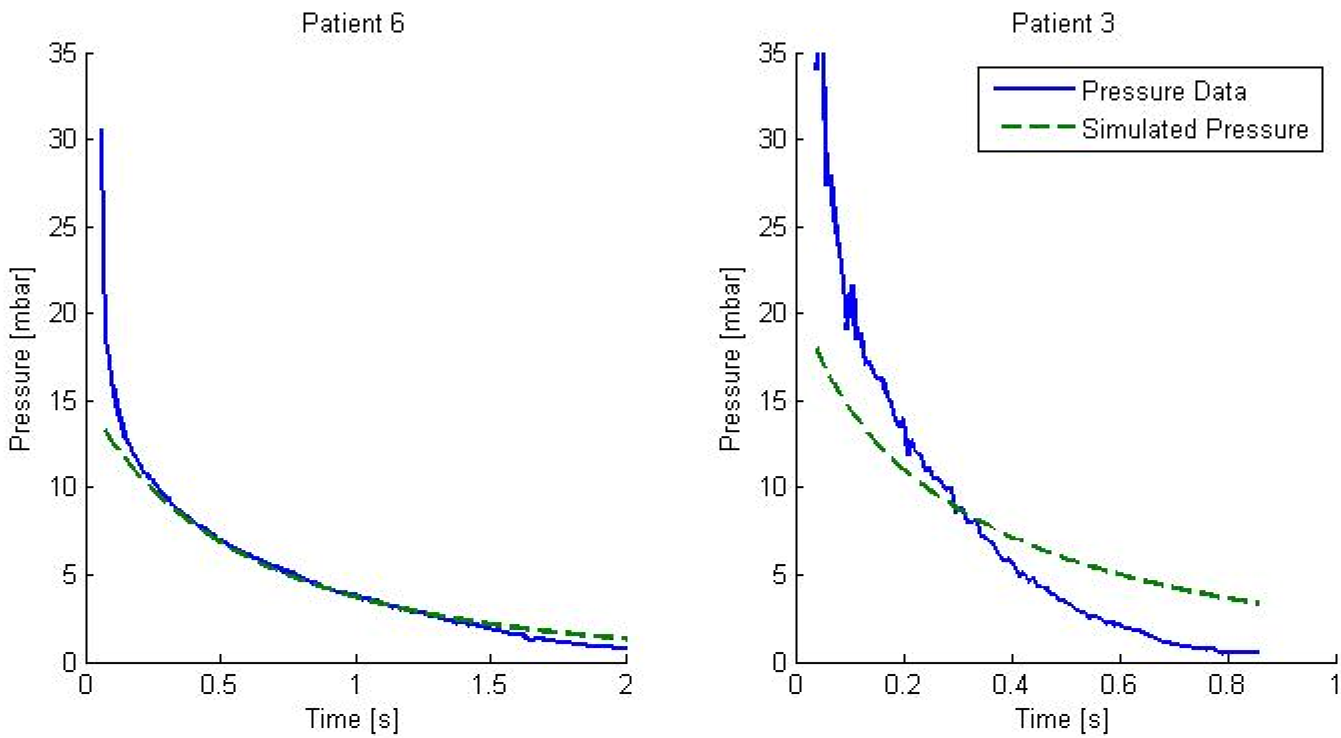
During expiration, to determine the recruitment status of a layer of lung units, threshold closing pressure (TCP) is required in addition to threshold opening pressure (TOP) used in inspiration as stated by Hickling [4]. During expiration, an opened lung unit remains open if the alveolar pressure is greater than the sum of superimposed pressures and TCP. Thus, if the VEPRM is successfully fitted to inspiration, the only free parameter required for fitting the model to the expiration is TCP. This identification is performed by a simplex search, using TOP as an initial estimate of TCP.

Airway pressure and flow data, sampled at 125Hz were measured from 12 mechanically ventilated ARDS patients. The study was approved by the local ethics committees of participating hospitals. The expiration data used comes from dynamic slice manoeuvres. The dynamic slice is an inspiration of 600mL/s for 2 seconds followed by free expiration. Data from low flow and static compliance automated single step manoeuvres are used for identification of inspiratory parameters, as explained in [1]. See [5] for a detailed description of the experimental setup. A hierarchical individualisation process is used to identify the VEPRM model parameters for inspiration. In this process, the simpler models are identified first, and then used as initial guesses for the more complex models [1,6].

Results: When fitting to the dynamic slice data, there was a very good fit on inspiration for 12 patients, coefficient of determination CD > 0.9. 4 patients had their inspiration parameters fitted well (CD > 0.9) to the expiration data with median [Interquartile range (IQR)] CD of 0.912[0.905-0.919]. 8 remaining patients had poor model fits with median [IQR] CD of 0.711[0.654-0.770].

In 6 patients, the identified TCP is greater than TOP which is not physiologically plausible and does not follow the recruitment model assumptions [4,7] where TOP is always higher than TCP. An identified TCP greater than TOP is an artefact of the numerical method for model fitting or a sign of mismatch between the model and the dynamics of reality. While some patients have poor model fits, it is of particular importance that there is systematic error, with pressure being underestimated at the beginning of expiration, and overestimated at the end of expiration as shown in Figure 1. This poor fitting suggests that some parameters that have been assumed constant for inspiration and expiration are actually different. It is likely that the resistance parameters used are not the same during inspiration and expiration. This difference is due to the flow having different geometry during inspiration, where the airways are bifurcating, from expiration, where airways are joining [8].

Figure:



Caption: The VEPRM model fitted to expiration for two different patients. The expiration of Patient 6 fits well to the model, whereas the model does not capture the behaviour exhibited by Patient 3.

Conclusion: The viscoelastic pressure dependent recruitment model can only be used to model expiration in 4 of 12 patients. In most patients, the parameters identified from inspiration no longer describe the pressure response of the lung during expiration. In order to use expiration data for respiratory mechanics models and to better understand respiratory processes, further studies are required to investigate which model parameters are the same in inspiration and expiration, and which are different.

Caption:

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Disclosure of Interest: None Declared