A 2 PARAMETER MODEL OF LUNG MECHANICS TO PREDICT VOLUME RESPONSE AND OPTIMIZE VENTILATOR THERAPY IN ARDS

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INTRODUCTION

A majority of patients admitted to the Intensive Care Unit (ICU) require some form of respiratory support. In the case of Acute Respiratory Distress Syndrome (ARDS), the patient often requires full intervention from a mechanical ventilator. ARDS is also associated with mortality rates as high as 70%. Despite many recent studies on ventilator treatment of the disease, there are no well established methods to determine the optimal Positive End expiratory Pressure (PEEP) ventilator setting for individual patients [1]. A model of fundamental lung mechanics is developed based on capturing the recruitment status of lung units. The model produces good correlation with clinical data, and is clinically applicable due to the minimal number of patient specific parameters to identify. The ability to use this identified patient specific model to optimize ventilator management and lung volume recruitment is demonstrated. It thus provides a platform for continuous monitoring of lung unit recruitment and capability for a patient.

METHODS

The main objective of this research is to develop the simplest possible model that is also clinically effective. The model presented represents the lung as a collection of lung units. A lung unit corresponds to sets of distal airways and attached alveoli. The lung is divided into several "horizontal" compartments to simulate different level of superimposed pressures. The compartment at the bottom experiences higher superimposed pressure than the ones above due to the weight of the lung. Recent studies suggest that recruitment and derecruitment is the dominant cause of volume change, rather than isotropic, "balloon like", expansion of alveoli as had been traditionally thought [2]. The model developed thus consists of lung units with only two possible states: recruited or not recruited. The recruitment and derecruitment of the modeled lung units are controlled by the distribution of Threshold Opening Pressure (TOP) and Closing Pressure (TCP), respectively. Threshold pressures are assumed to follow a normal distribution along pressure based on studies in the literature.

Once a lung unit is opened, it assumes a volume defined by a unit compliance curve. The unit compliance is based on a sigmoid curve. A total of four variables are used to capture the essential features of the measured pressure volume curves: TOP distribution mean and standard deviation, and TCP distribution mean and standard deviation. These parameters are effectively two each for the inflation and deflation limbs. Other variables, such as PEEP, PIP, and tidal volume are assumed known as they are set by the clinician or can be obtained directly from the ventilator.

RESULTS AND DISCUSSION

The model is validated by fitting and predicting with clinical PV data of 12 patients at different PEEP levels. The TOP and TCP parameters are identified from the data. Different PEEP settings are fitted by shifting only the distribution mean value, while other parameters were fixed.

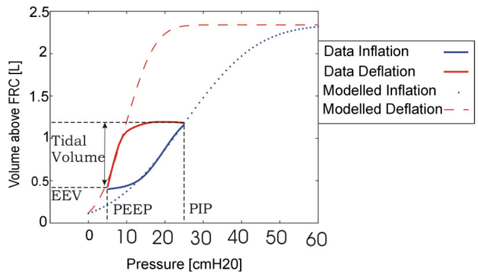

Figure 1: Minimal model being fitted to a PV loop at a PEEP = 5 cm H_2O

Using data from 2 PEEP settings a prediction can be made for the third or fourth. The overall average absolute error in the pressures at given volume varied from 15.92 ml (1.81%) to 20.65 ml (3.41%) for inflation and 36.63 (4.08%) to 41.06 ml (7.18%) for deflation.

Shifting of the means of the TOP and TCP distributions, while keeping standard deviation fixed, matched clinical data well. A mean shift represents the effect of the dynamic mechanism of lung units at different PEEP values. More specifically, once a collapsed lung unit is recruited, it does not necessarily collapse again at a given pressure. Instead, it stays recruited at a lower pressure due to PEEP. This effect is especially significant in the ARDS lung because of the reduced number of functional lung units and lower compliance of the overall lung. The benefit of recruitment manoeuvres on ventilated patients is based on this dynamic.

The methods also allowed accurate prediction of lung response to data not used in the identification. Therefore, the model captures volume response to different PEEP values. It can thus provide constant monitoring for a patient's level of lung recruitment, and capability of recruitment.

CONCLUSIONS

A minimal model of the mechanics of a ventilated lung is developed. It employs only 2 unique parameters for each limb of the breathing cycle. The model was validated by using clinical data. It provides accurate predictions of various PEEP. These results shows that the model could be used to both monitor a patients condition and predict the volume response to PEEP. Full clinical trials to prove this capability are planned for 2009.

REFERENCES

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2. Schiller HJ, et al. *Critical care medicine* 2003; **31**(4):1126-33