

# MINIMAL MODEL OF LUNG MECHANICS FOR OPTIMIZING VENTILATOR TREATMENT IN ARDS

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**Introduction:** A significant number 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 rate 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. 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 is demonstrated. This minimal model also provides a clinically useful, simple platform for continuous monitoring of lung unit recruitment 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. The model developed thus consists of lung units with only two possible states: recruited or not recruited. The recruitment and derecruitment of the modelled 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:** The model is validated by fitting and predicting with clinical PV data of 4 patients at different PEEP levels. The TOP and TCP parameters were fit parametrically. Data from different PEEP settings of the same patient were fitted by shifting the distribution mean value, while other parameters were fixed. Prediction is done by using data from 2 PEEP settings to predict the third, or by using data from 3 PEEP settings to predict the fourth. For the four patients the overall average absolute error in the pressures 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. Note that the prediction only occurred in the steady portion of the curve to avoid the transition regions.

**Discussion:** The shifting of the means of the TOP and TCP normal distributions while keeping standard deviation fixed, gave good matches to the clinical data. 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 the same pressure at which it was recruited. Instead, it stays recruited at a lower pressure. 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 a good prediction of lung response to data not used in the identification. Therefore, there is a potential to use the model to trial and test various PEEP settings before application to the patient. Another benefit of this approach is to provide constant monitoring for a patient's level of lung recruitment, and thus the level of ARDS and the impact of therapy as the patient's condition evolves.

**Conclusion:** 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 fitting to clinical data and predicting lung response to various PEEP settings. These initial results show that the model could be used to both monitor a patients condition and predict PEEP therapy response. Longer term this approach may lead to improved management of ARDS in critical care.