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Opening and closing time of alveolar and recruitment / decruitment of ARDS patients lung

Abstract: Introduction: Our contribution shows smooth temporal recruitment and decruitment of ARDS lungs by considering the opening and closing time of alveolar of acute respiratory distress syndrome (ARDS) patient. **Methods:** The calculation of all tasks is based on two mathematical expressions. one calculates the opening fraction and another is closing fraction time. **Results**: The representation of recruitment and decruitment, opening and closing time, effect of different PEEP on P/V curves impact of both constant in P/V curves. **Discussion:** The variation of time at different pressures and effect of constants by using different values on P/V curve. The effect of constants on P/V curves. **Conclusion:** By implementing this mathematical expression we are able to find the opening and closing time for each compartment and smooth opening of lung.

Keywords: Recruitment, decruitment, Acute respiratory distress syndrome (ARDS), Positive end expiratory pressure, Pressure/Volume curve

1 Introduction

The patient, who suffers with deoxygenation or breath less due to some reason such as fluid enter into the alveoli causes less volume of alveoli as a result the exchange of air is less in lung is said as ARDS patient. PEEP (Positive end expiratory pressure) is required to prevent the end expiratory collapsed alveoli [1] which is set by mechanical ventilation.Lung injury occurs due to Inapropriate ventilation and increase the rate of mortality [2].This is happened because there is lack of information about the characteristic of alveoli.The alveaolar is opened by providing the maximum pressure then there is possibility that alveoli collapsed. The smooth recruitment and derecruitment is necessary to prevent a lung injury due to Ventilation.In this report,we implement a mechanism to calculate the pressure as well as a time to opening and closing of every layer of the lung. This mechanism helps to prevent the collapsing alveoli or lung injury during ventilation. The mechanism consists two equations for opening time and closing time that depends on two different constants (open and close), Superimposed pressure (SP) (The pressure is needed to affect the layer), Critical pressure (The pressure at which the alveolar start to open) and Threshold opening pressure (The alveolar pressure before the volume of the alveoli increases above zero) ,Positive end expiratory pressure(PEEP) (The pressure already exist in the lung when new inspiration cycle starts) [1].

2 Method

In this report, the calculation of opening and closing time is based on Jason H. T. Bates, and Charles G. Irvin [2]. In addition, we used a non-linear compliance from Hickling model and the volume from the Salazar Knowles V = A - B*e^{kp}, where A = B = 0.01, k = 0.03, V is the volume of the alveolar and p is the alveolar pressure. In order to find the opening time and closing time of each layer, we add two variable open and close with different condition. If the alveolar pressure of the alveoli is greater than critical pressure then we can say that the alveolar begins to open and if the alveolar pressure is smaller than critical pressure then the alveolar remains closed. The critical pressure is the sum of superimposed pressure and threshold opening

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pressure. The mathematical representation is shown below to find opening and closing time.

dOpen /dt = Const *(P(t) - P_crit)
ifP(t)>P_crit ....(1)

dOpen /dt = Const_c *(P(t) - SP)
ifP(t)<SP ....(2)

From equation (1) we calculate the value of open variable. It is distributed from 0 to 1. The alveolar is fully open if the value of open reaches to 1. Equation (2) is for the close variable. The initial value of close variable is 1 and if it is equal to or close to zero (1 to 0) then the alveolar is closed. This gives the relation between pressure and time for each layer. The constants used in both equations are different for open the value of constant is 0.05(cmH_2o) and for close the value of constant is also 0.05(cmH_2o).
Further to get the smooth opening recruitment curve, the condition for open variable is from 0.9 to 1.
The following parameters used in this calculation:
TOPmin = 0(cmH_2O); TOPmax = 0(cmH_2O);
K = 0.03(cmH_2O); A= 0.01(cmH_2O);
B = 0.01(cmH_2O); Open constant = 0.05(cmH_2O);
Close constant = 0.05(cmH_2O)

3 Results

First task is to find the time required to open thresold by imposing sudden pressure.In all task we use the salazar model and non linear hickling compliance. By using equation(1) We get time required to open for each compartment and also observed the pressure time relation in every layer. As shown in figure 1 The representation of time of every compartment at different pressure.

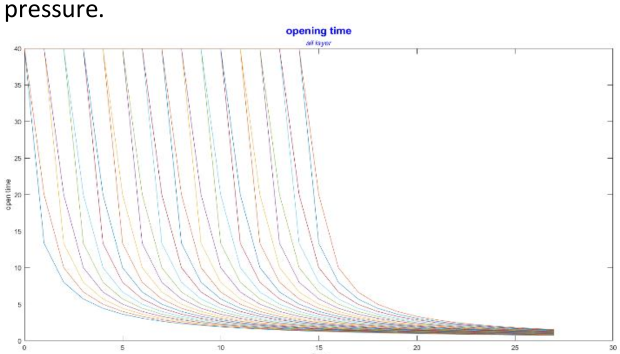

Figure 1: *Represent the opening time of all layers*

Smooth recruitment is found by putting the initial value of open variable is 0.9 instead of zero which means the time is calculated between 0.9 to 1 therefore the time required to open the compartment is less as compared to open fraction 0 to 1. As shown in figure 2 the smooth opening by using this condition.

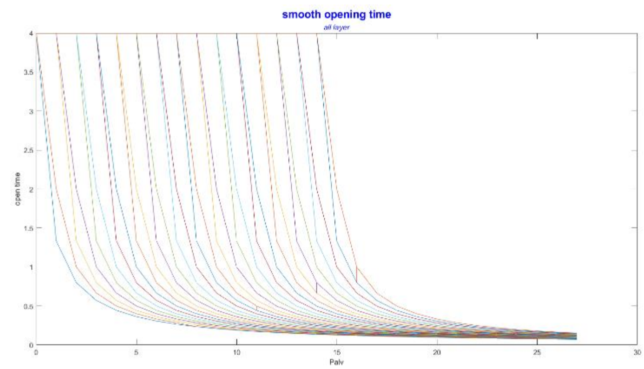

Figure 2: *Shows the smooth opening time of all layers*

The P/V curves with different PEEP (0,4,5,12) by using Salazar model and nonlinear Hickling compliance and it depicts that it working properly with different PEEP an shown in figure 3.

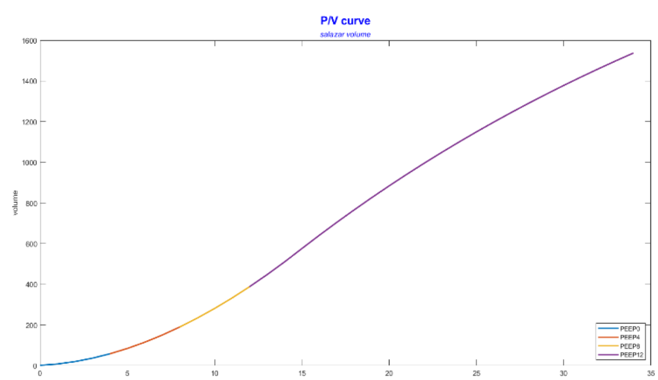

Figure 3: *P/V curve with different PEEP*

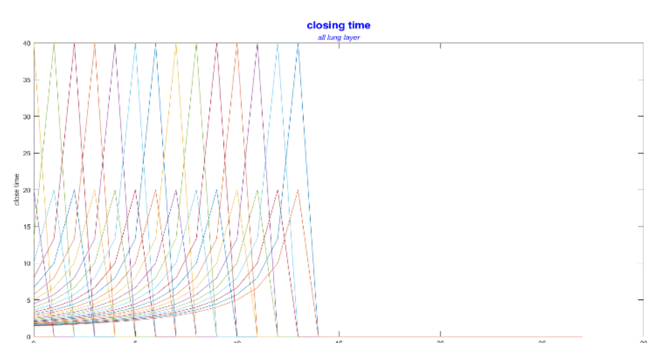

Figure 4: *Represents the closing time of all layers*

In second task, we used equation (2) to find the closing time same as task 1. As shown in figure 4 the closing time of each layer at different pressure.

The influence of opening constant and closing constant on P/V curves as shown in figure 5.

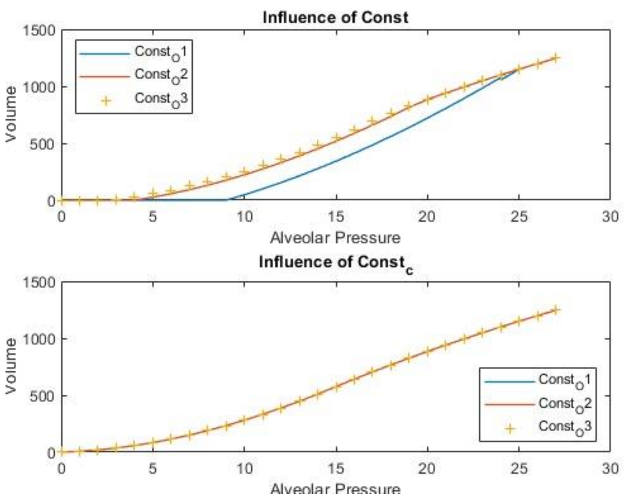

Figure 5: *The effect of different constants on P/V curve. Top figure shows the effect of opening constant and bottom one shows the influence of closing constant.*

4 Discussion

As per the result of opening time of all compartments is more at less pressure. At maximum pressure the 25, the time required to open the alveolar is around 1 second as shown in figure 1. In smooth opening range of time is less. In figure 4, if the pressure is high then the time required to close is more. For all layers the closing pressure is different at maximum time.

Figure 3 demonstrate that at different PEEP levels model is working properly. From figure 5, the value of opening constant is 1,2 and 3. All values creates the different P/V curves. By increasing the opening constant volume between the end expiratory and peak inspiratory pressure increases and time required to open the layer is less while in closing its same for these values.

5 Conclusion

This report provides all results of given tasks. The lung injury of ARDS patient during ventilation. To prevent this injury, it is necessary to obtain a correct opening and closing time. In our contribution we are able to find the smooth recruitment and decruitment with the help of equation 1 and 2. The role of both constants on P/V curves and the effect of different PEEP levels on P/V curve.

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