University of Moratuwa, Sri Lanka

Department of Electronic & Telecommunication Engineering

Simulation of Respiratory Mechanics

BM2102 Modelling and Analysis of Physiological Systems

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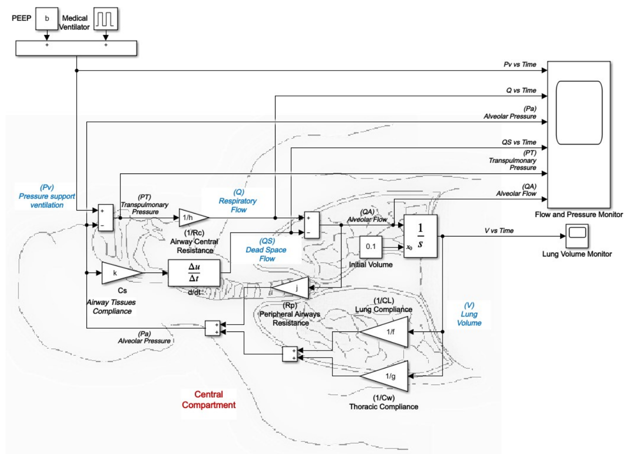
Contents

1 Introduction

The behaviour of the human respiratory system can be modelled using modern modelling software with the inclusion of essential pulmonary characteristic parameters. Such an attempt is published and open-sourced by [1] as a MATLAB Simulink project. This report discusses the behaviour of three main pulmonary conditions, simulated with the help of the above Simulink model.



Overview of the respiratory system model. The system can be divided into two main parts; Central airway and peripheral airways.

2 Important Model Parameters

The system overview shows parameters such as resistances to airflow in central (h) and peripheral (j) airways, alveolar volume, and dead space volume. The GUI window allows setting the following key variables.

2.1 Physiological Parameters

- Lung compliance: A measure of expansive ability of lungs
- Thoracic compliance: A measure of expansive ability of thorax
- Airway central resistance: Resistance to airflow in the central part (Trachea)
- Peripheral airway resistance: Resistance to airflow in the peripheral parts (Bronchi, bronchioles)
- Airway tissue compliance: Expansive ability of tissues in airways

2.2 Ventilator Parameters

This system does not model the diaphragm, but instead uses an external ventilator.

- Breathing frequency: Rate of inhalation/exhalation
- PEEP (Positive End-Expiratory Pressure): Airway pressure at end of exhalation
- Peak pressure: Maximum airway pressure at inhalation

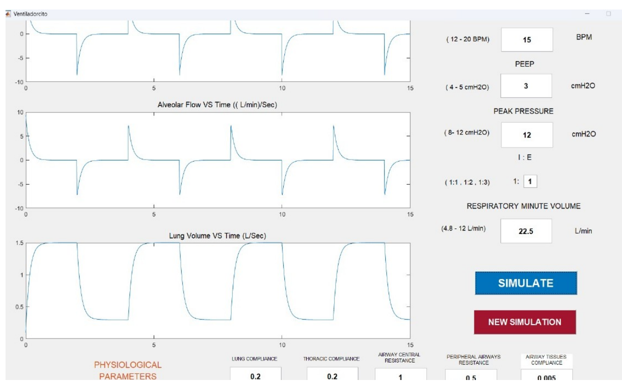
3 Simulation for Normal Conditions

Parameters:

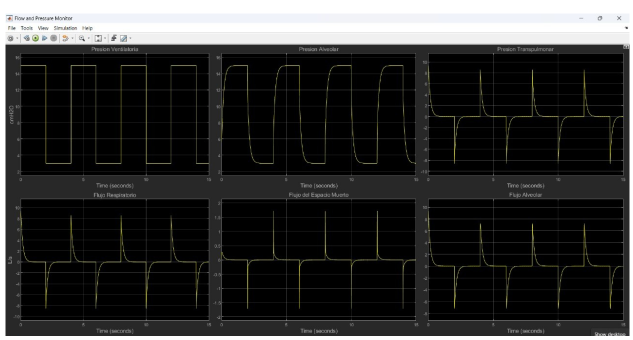
- Lung compliance: 0.2 L/cmH_2O
- Thoracic compliance: 0.2 L/cmH_2O
- Airway central resistance: 1 cmH_2O/L/s
- Peripheral airway resistance: 0.5 cmH_2O/L/s
- Airway tissue compliance: 0.005 L/cmH_2O

Ventilator Settings:

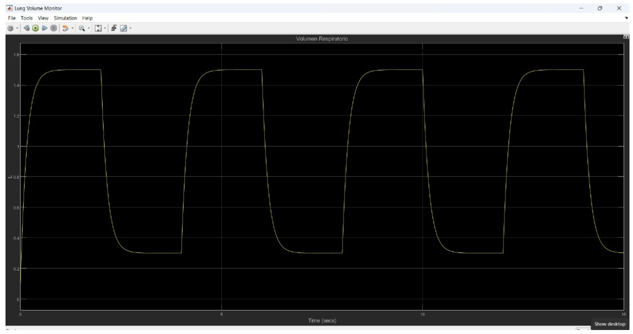
- Breathing frequency: 15 BPM
- PEEP: 3 cmH_2O
- Peak pressure: 12 cmH_2O



Graphs under normal pulmonary conditions. Respiratory minute volume is 22.5 L/min. Peak lung volume is 1.5 L/sec.



Flow and Pressure Monitor in Normal Condition



Lung Volume Monitor in Normal Condition

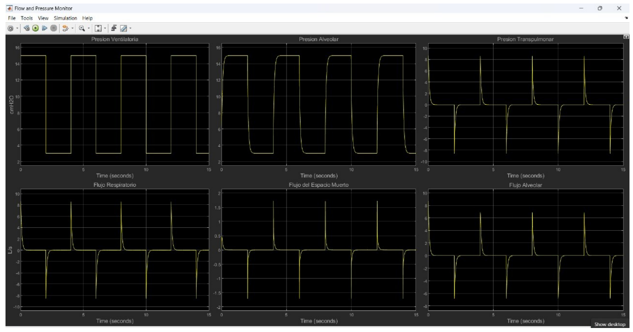
4 Simulation for Restrictive Pulmonary Disease Conditions

Restrictive Pulmonary Diseases reduce overall lung volume and elasticity due to reduced compliance. Example: Fibrosis.

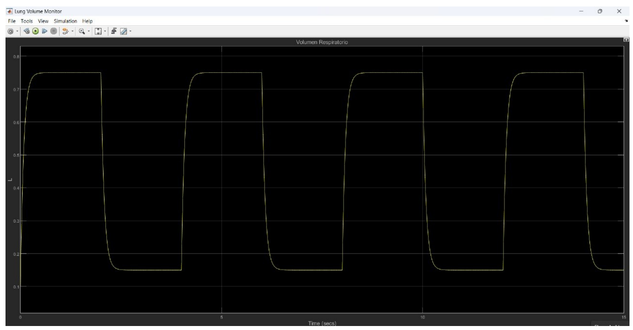
Parameters:

- Lung compliance: 0.1 L/cmH_2O
- Thoracic compliance: 0.1 L/cmH_2O
- Airway central resistance: 1 cmH_2O/L/s
- Peripheral airway resistance: 0.5 cmH_2O/L/s
- Airway tissue compliance: 0.005 L/cmH_2O

Graphs under restrictive pulmonary disease. Minute volume = 11.25 L/min. Peak lung volume = 0.75 L/sec..



Flow and Pressure Monitor under restrictive pulmonary disease



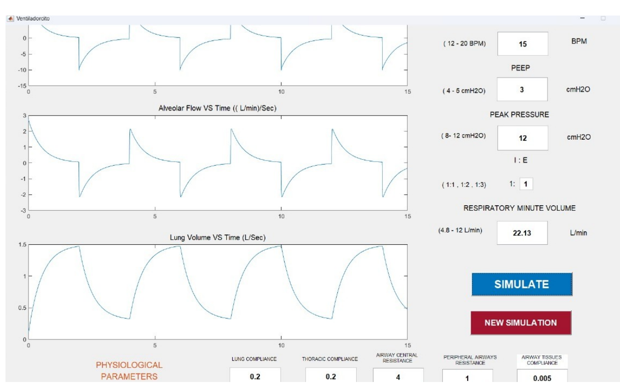
Lung Volume Monitor under restrictive pulmonary disease.

5 Simulation for Obstructive Pulmonary Disease Conditions

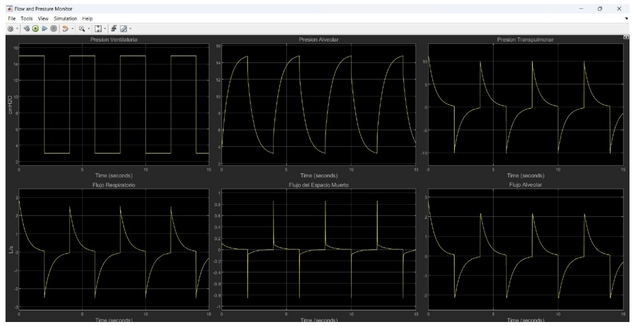
Obstructive diseases (e.g., asthma, bronchitis, emphysema) increase resistance in airflow.

Parameters:

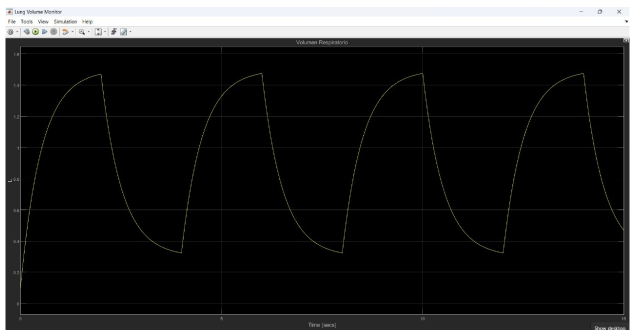
- Lung compliance: 0.2 L/cmH_2O
- Thoracic compliance: 0.2 L/cmH_2O
- Airway central resistance: 4 cmH_2O/L/s
- Peripheral airway resistance: 1 cmH_2O/L/s
- Airway tissue compliance: 0.005 L/cmH_2O



Graphs under Obstructive Pulmonary Disease Conditions. Respiratory minute volume is 22.13 L/min. Peak lung volume is 1.5 L/sec.



Flow and Pressure Monitor under Obstructive Pulmonary Disease Condition.



Lung Volume Monitor Obstructive Pulmonary Disease Condition.

6 Comparison of Minute Ventilation

According to [3],

$$\text{Minute Ventilation} = \text{Respiratory Rate} \times \text{Tidal Volume} \tag{1}$$

Summary:

- Normal condition: 22.5 L/min
- Restrictive condition: 11.25 L/min
- Obstructive condition: 22.13 L/min

Restrictive conditions reduce ventilation due to low lung volume. Obstructive conditions increase dead space, but minute volume may still increase due to prolonged expiration.

7 References

References

[1] David Leonardo Rodriguez Sarmiento and Daniela Acevedo Guerrero (2020). *Simulation of Respiratory Mechanics on Simulink with GUI*, MATLAB Central File Exchange. https://www.mathworks.com/matlabcentral/fileexchange/75335-simulation-of-respiratory-mechanics-on-simulink-with-gui

[2] #SimulinkChallenge2019: *Simulation of Respiratory Mechanics with Simulink*. https://www.youtube.com/watch?v=b97brGo2Dk0

[3] S. Hallett, F. Toro, and J. V. Ashurst, "Physiology, Tidal Volume," PubMed, 2021. https://www.ncbi.nlm.nih.gov/books/NBK482502/