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Simulation of Respiratory Mechanics

BM2102 Modelling and Analysis of Physiological Systems

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1 Introduction

This report explores the simulation of respiratory mechanics using the MATLAB Simulink model developed by David Leonardo Rodriguez Sarmiento and Daniela Acevedo Guerrero [**?**]. It simulates respiratory conditions for:

- A healthy adult
- An adult with a restrictive pulmonary disease
- An adult with an obstructive pulmonary disease

The purpose is to observe the differences in minute ventilation and breathing mechanics across these scenarios.

2 Important Model Parameters

To simulate the dynamics of human respiration, we need to consider both the biological properties of the respiratory system and the mechanical behavior of the ventilator. These parameters are organized into two main categories: internal physiological characteristics and external control via the ventilator. Instead of listing them linearly, the table below gives a structured comparison.

System Overview Table

Parameter	**Description**
Lung Compliance	Reflects how easily the lungs can stretch when pressure is applied. Lower values indicate stiffer lungs, common in restrictive diseases.
Thoracic Compliance	Measures the ability of the chest wall to expand. Reduced in conditions like obesity or musculoskeletal limitations.
Airway Central Resistance	The airflow resistance through the trachea and main bronchi; higher values make it harder for air to move in and out.
Peripheral Airway Resistance	Represents resistance in the smaller airways, especially bronchioles. This is elevated in obstructive diseases like asthma.
Airway Tissue Compliance	Indicates the flexibility of the airways themselves, which helps maintain proper lung recoil and pressure dynamics.

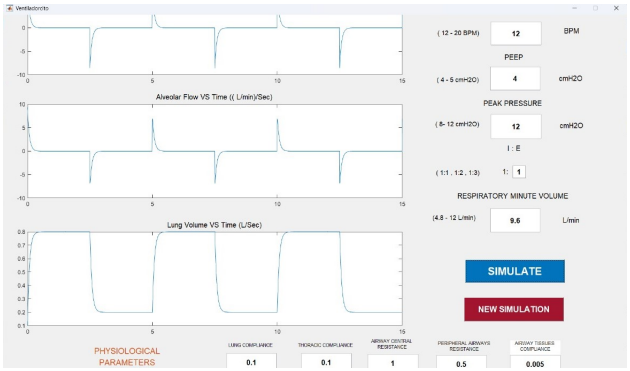
Table 1: Physiological Parameters Affecting Breathing

3 Normal Adult

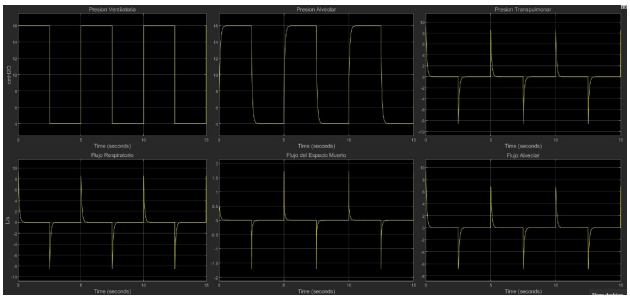
The baseline simulation represents a healthy adult lung with normal compliance and airway resistance.

Simulation Parameters

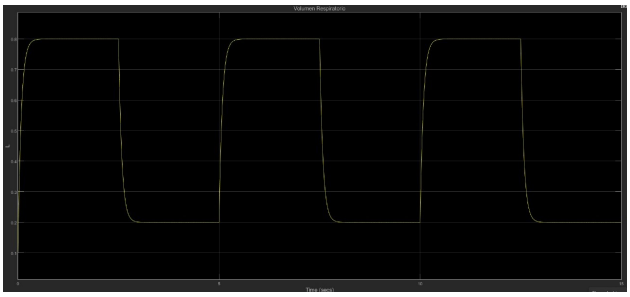
- Lung Compliance: 0.1 L/cmH_2O
- Thoracic Compliance: 0.1 L/cmH_2O
- Central Resistance: 1 cmH_2O/L/s
- Peripheral Resistance: 0.5 cmH_2O/L/s
- Airway tissue compliance: 0.005 L/cmH_2O
- Respiratory Rate: 12 BPM
- PEEP: 4 cmH_2O
- Peak Pressure: 12 cmH_2O



Graphs under normal pulmonary conditions. Respiratory minute volume is 9.6 L/min. Peak lung volume is 0.8 L/sec.



Flow and Pressure Monitor in Normal Condition



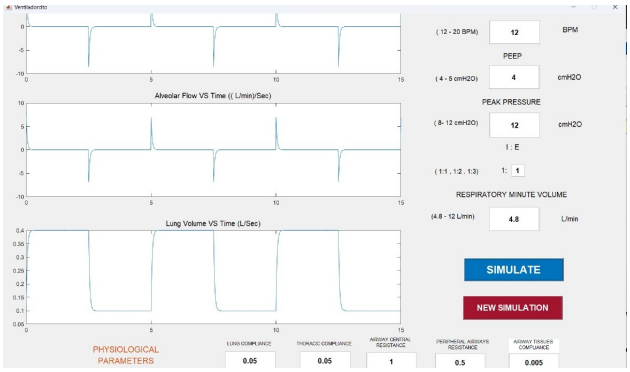
Lung Volume Monitor in Normal Condition

4 Restrictive Pulmonary Disease: Pulmonary Fibrosis

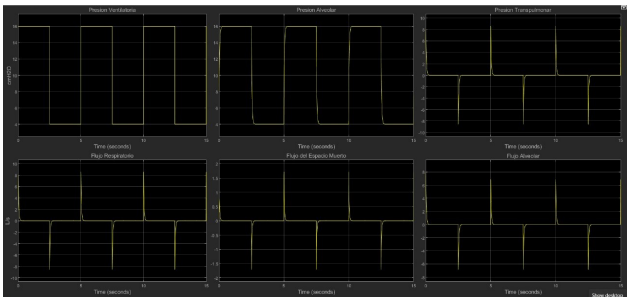
Restrictive diseases limit the expansion of the lungs due to stiff tissue or chest wall.

Simulation Parameters

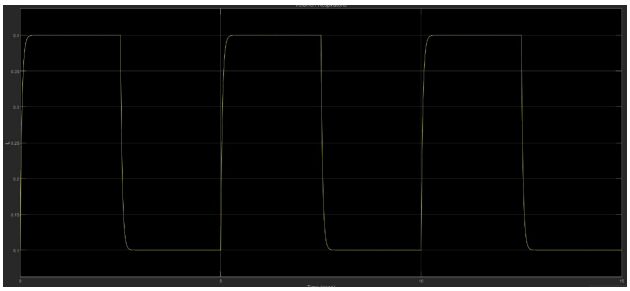
- Lung compliance: 0.005 L/cmH_2O
- Thoracic compliance: 0.005 L/cmH_2O
- Airway central resistance: 1 cmH_2O/L/s
- Peripheral airway resistance: 0.5 cmH_2O/L/s
- Airway tissue compliance: 0.005 L/cmH_2O
- Breathing frequency: 12 BPM
- PEEP: 4 cmH_2O
- Peak pressure: 12 cmH_2O



Graphs under restrictive pulmonary disease. Minute volume = 4.8 L/min. Peak lung volume = 0.4 L/sec..



Flow and Pressure Monitor under restrictive pulmonary disease



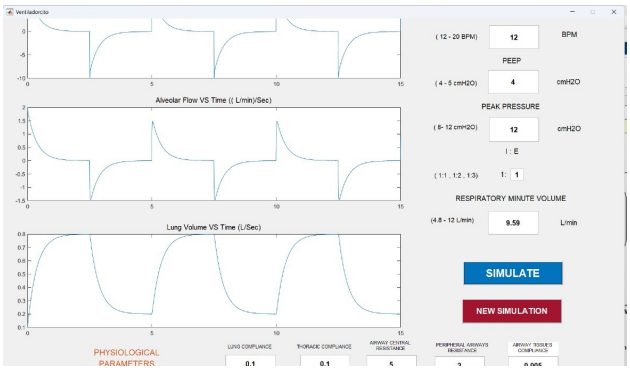
Lung Volume Monitor under restrictive pulmonary disease.

5 Obstructive Pulmonary Disease: Asthma

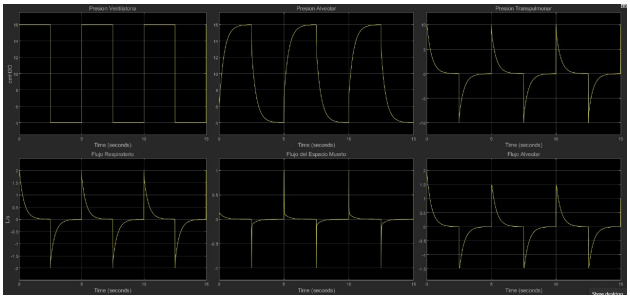
Obstructive diseases cause difficulty in exhaling air due to narrowed airways.

Simulation Parameters

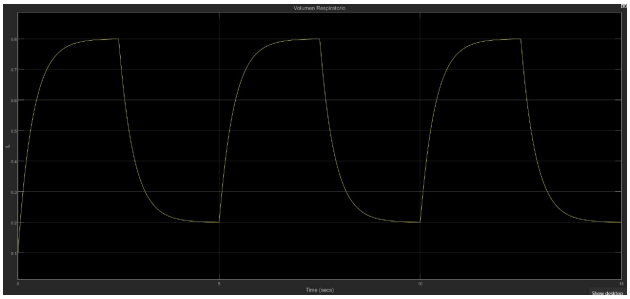
- Lung compliance: 0.1 L/cmH_2O
- Thoracic compliance: 0.1 L/cmH_2O
- Airway central resistance: 5 cmH_2O/L/s
- Peripheral airway resistance: 2 cmH_2O/L/s
- Airway tissue compliance: 0.005 L/cmH_2O
- Breathing frequency: 12 BPM
- PEEP: 4 cmH_2O
- Peak pressure: 12 cmH_2O



Graphs under Obstructive Pulmonary Disease Conditions. Respiratory minute volume is 9.59 L/min. Peak lung volume is 0.8 L/sec.



Flow and Pressure Monitor under Obstructive Pulmonary Disease Condition.



Lung Volume Monitor Obstructive Pulmonary Disease Condition.

6 Comparison of Minute Ventilation

Condition	Minute Ventilation (L/min)
Normal	9.6
Restrictive (Fibrosis)	4.8
Obstructive (Asthma)	9.59

Table 2: Comparison of Minute Ventilation

7 Conclusion

Simulation results show that:

- Normal lungs maintain regular airflow and pressure cycles with effective ventilation (around 9.6 L/min).
- Restrictive diseases reduce lung volumes and compliance, leading to low minute ventilation and a risk of hypoventilation.
- Obstructive diseases increase resistance, prolonging expiration and creating air-trapping despite near-normal minute volume.

These insights reinforce the need to adapt ventilator settings according to the pathology for effective respiratory support.