University of Moratuwa
Faculty of Engineering
Department of Electronic & Telecommunication Engineering

Modelling and Analysis of Physiological Systems

Simulation of Respiratory Mechanics

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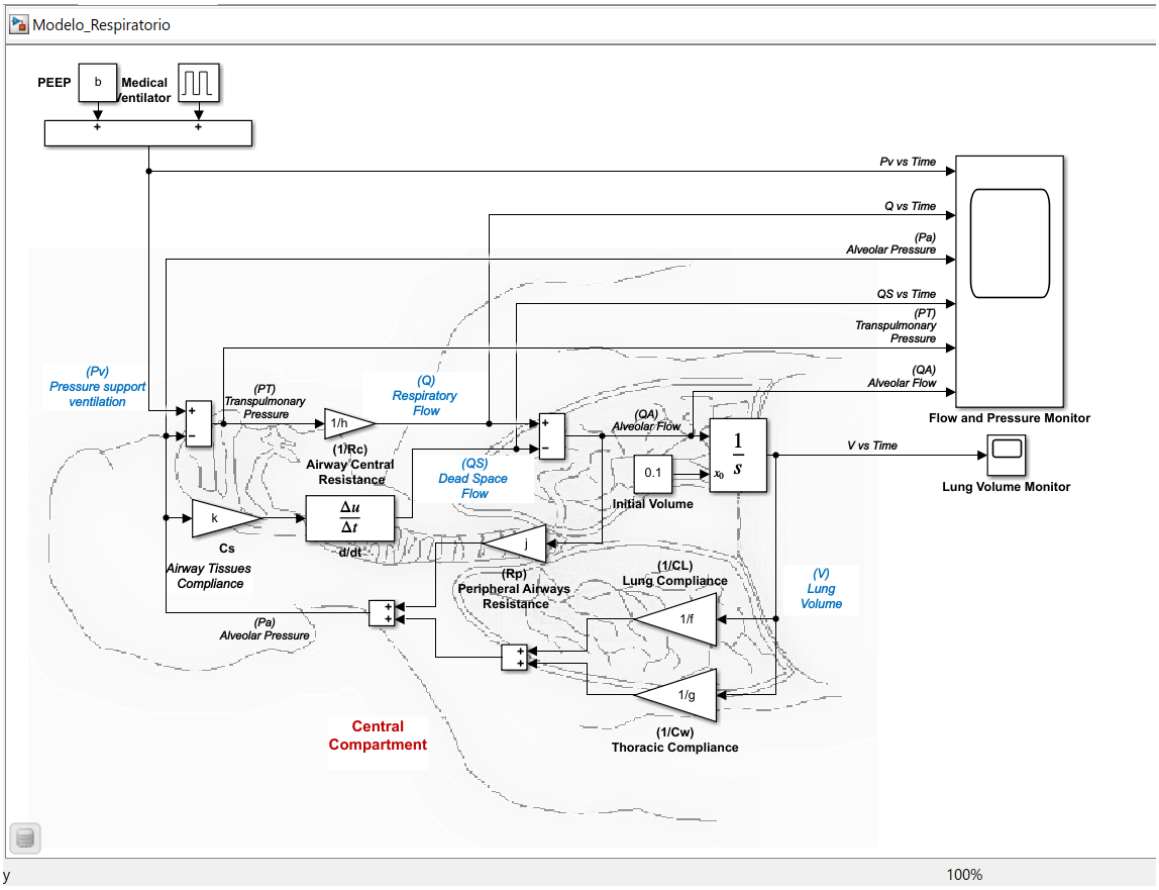
Contents

The simulator developed by David Leonardo Rodriguez Sarmiento and Daniela Acevedo Guerrero (2020) is used for following simulations.



1 Normal person

As given in the lecture notes,

Lung Compliance	$= 0.1\ L/cmH_2O$
Thoracic Compliance	$= 0.1\ L/cmH_2O$
Airway Central Resistance	$= 3.0\ cmH_2O/(L/s)$
Airway Peripheral Resistance	$= 0.5\ cmH_2O/(L/s)$
Airway tissues Compliance	$= 0.005\ L/cmH_2O$

This normal person will be connected to ventilator with;

Breathing frequency	$= 15$ BPM
PEEP	$= 0\ cmH_2O$
Peek Pressure	$10\ cmH_2O$
I:E	1:1

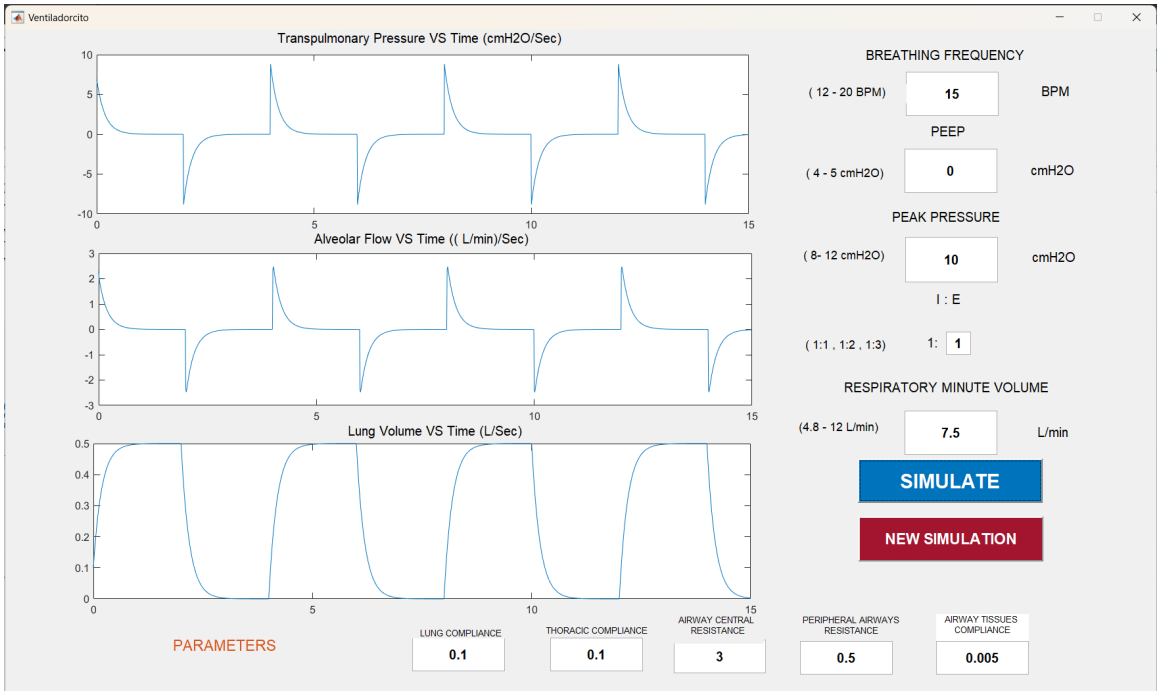


Figure 1: Ventiladorcito

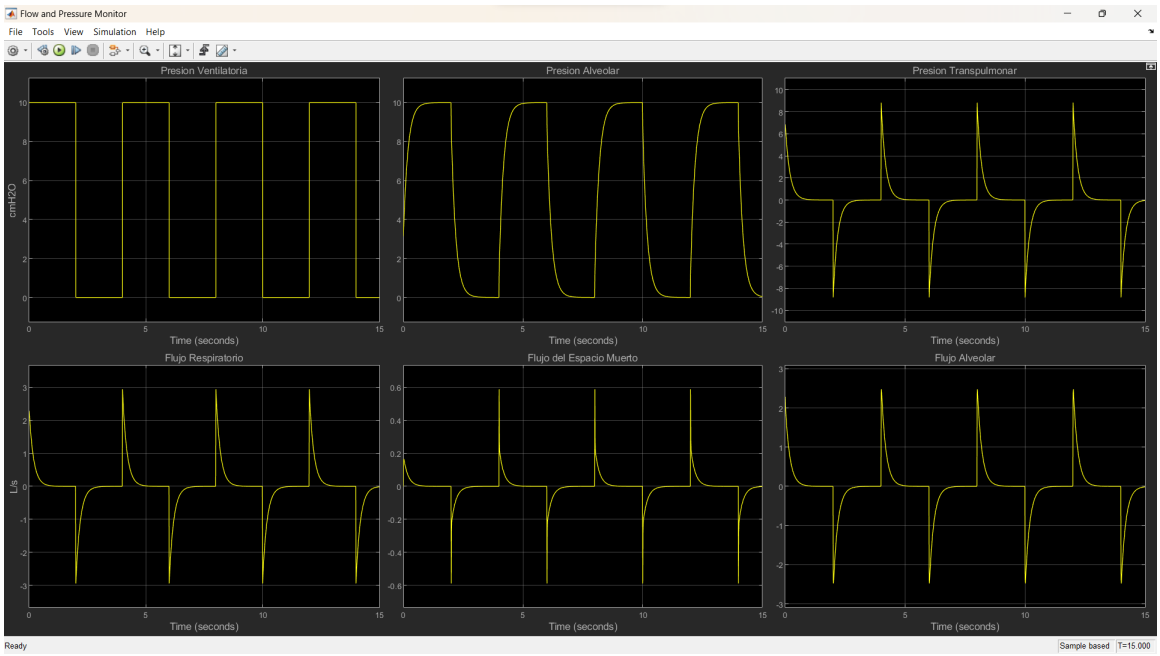


Figure 2: Flow and Pressure Monitor

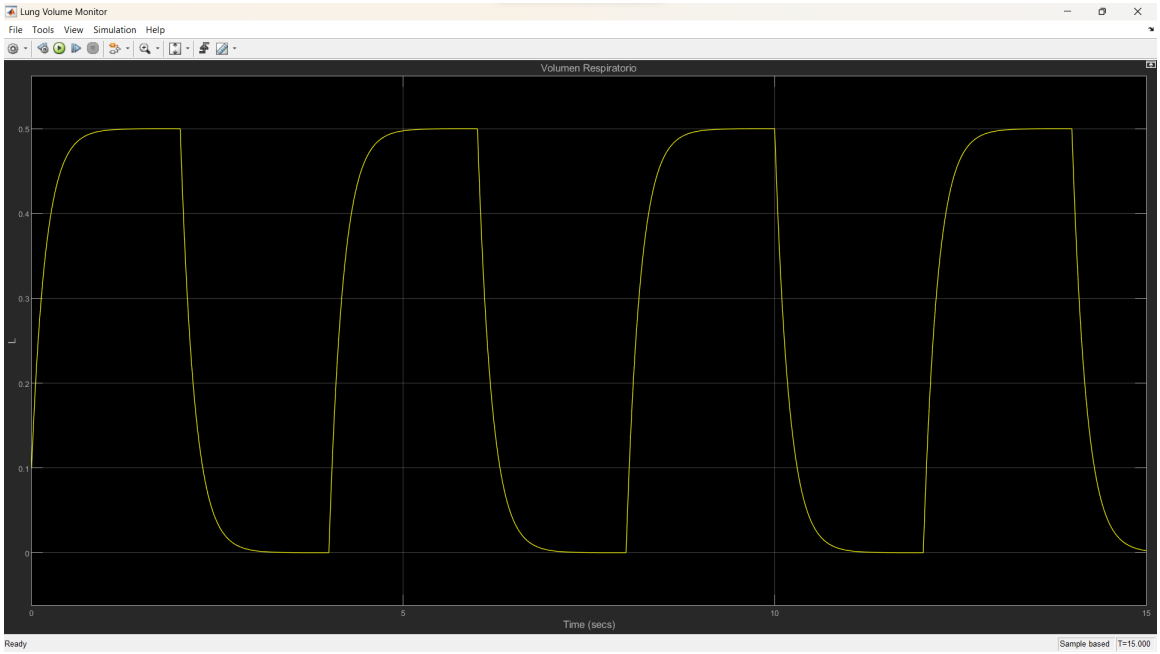


Figure 3: Lung Volume Monitor

2 A person with a restrictive pulmonary disease

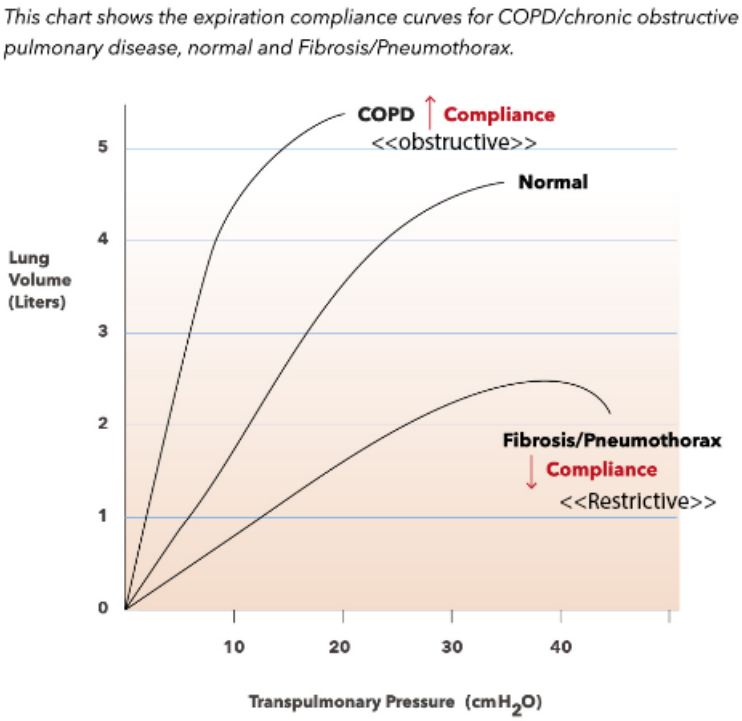


Figure 4: Differncce between the diseases

Restrictive lung diseases, also known as interstitial lung diseases, are a group of respiratory conditions characterized by reduced lung expansion and decreased lung volume. In these conditions, the lungs' ability to expand fully during inhalation is limited, leading to difficulty in taking deep breaths and a reduced capacity for oxygen exchange. Restrictive lung diseases affect the lung tissue and the chest wall, causing impairment in the mechanics of breathing.

There are several types of restrictive lung diseases, each with different underlying causes and features. Some common examples include:

- Idiopathic Pulmonary Fibrosis (IPF): IPF is a progressive and often fatal lung disease where the lung tissue becomes scarred and thickened over time. This scarring, known as fibrosis, hinders the lung's ability to expand and contract properly, leading to breathing difficulties.
- Sarcoidosis: Sarcoidosis is an inflammatory disease that can affect multiple organs, including the lungs. In pulmonary sarcoidosis, small clusters of inflammatory cells form in the lung tissue, leading to scarring and impaired lung function.
- Occupational Lung Diseases: Certain work environments, like coal mining, construction, or exposure to harmful substances like asbestos, silica, or beryllium, can cause restrictive lung diseases due to chronic exposure to irritants.
- Rheumatoid Arthritis-associated Interstitial Lung Disease: Rheumatoid arthritis (RA) is an autoimmune disease that, in some cases, can lead to inflammation and scarring in the lungs, resulting in restrictive lung disease.
- Obesity-related Restrictive Lung Disease: Severe obesity can reduce lung expansion by compressing the lungs and decreasing chest wall compliance.
- Neuromuscular Disorders: Certain conditions that weaken the muscles involved in breathing, such as muscular dystrophy or amyotrophic lateral sclerosis (ALS), can lead to restrictive lung disease.

Symptoms of restrictive lung diseases include shortness of breath, dry cough, fatigue, and chest discomfort. Main reason is lower lung compliance. As compliance reduces, more pressure will be needed to inflate the lungs which reduces the volume and the minute respiration, PEEP, and peak pressure need to be increased to support the lungs.

The following values are approximated to have the described property as i was unable to find exact values of any of the mentioned diseases.

Lung Compliance	$= 0.05\ L/cmH_2O$
Thoracic Compliance	$= 0.05\ L/cmH_2O$
Airway Central Resistance	$= 3.0\ cmH_2O/(L/s)$
Airway Peripheral Resistance	$= 0.5\ cmH_2O/(L/s)$
Airway tissues Compliance	$= 0.005\ L/cmH_2O$
Breathing frequency	= 20 BPM
PEEP	$= 3\ cmH_2O$
Peek Pressure	$12\ cmH_2O$
I:E	1:2

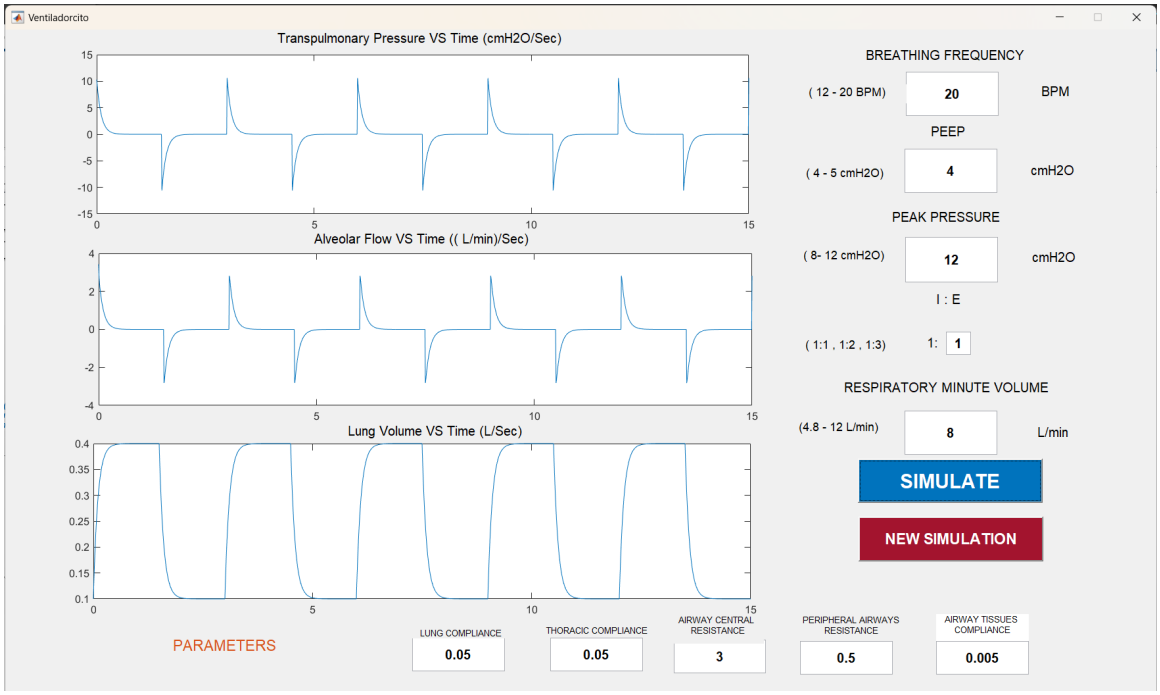


Figure 5: Ventiladorcito

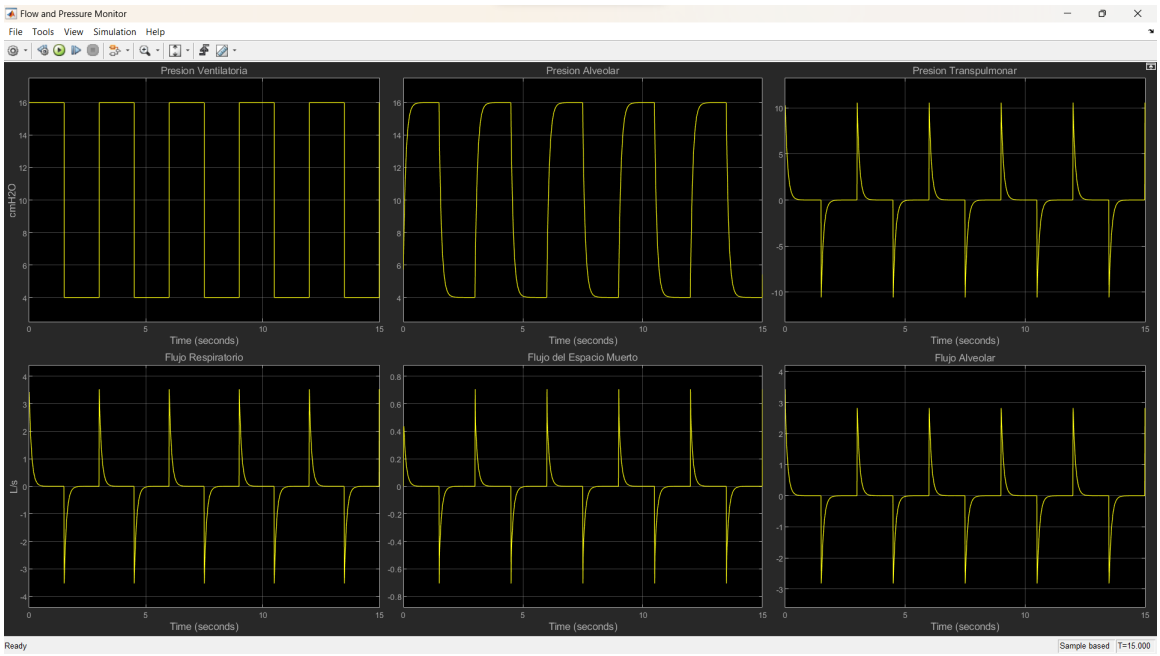


Figure 6: Flow and Pressure Monitor

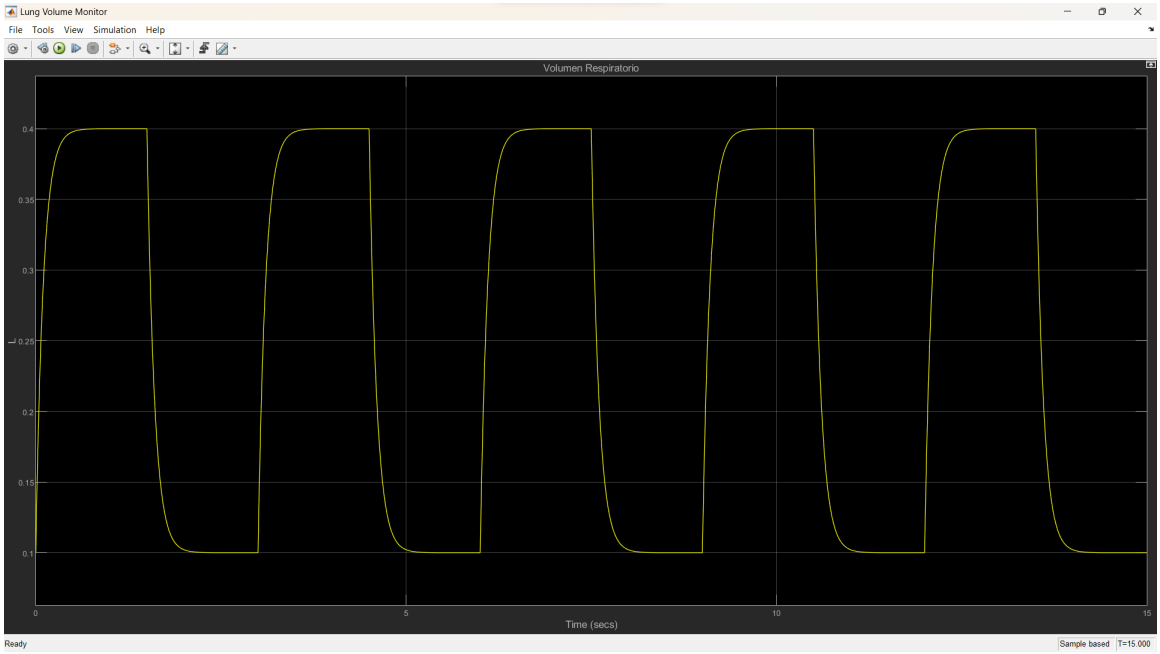


Figure 7: Lung Volume Monitor

Respiratory minute volume is in range for the patient.

3 A person with an obstructive pulmonary disease

Obstructive pulmonary diseases are a group of chronic respiratory conditions characterized by airflow limitation, making it difficult for individuals to exhale air from their lungs effectively. In these diseases, there is increased resistance to airflow due to various factors such as narrowed airways, inflammation, and increased mucus production. As a result, people with obstructive lung diseases experience breathing difficulties, especially during exhalation. For examples,

- Chronic Obstructive Pulmonary Disease (COPD): COPD is one of the most common obstructive lung diseases and is often associated with smoking. It includes conditions like chronic bronchitis and emphysema. In chronic bronchitis, the airways become inflamed and narrowed, leading to excessive mucus production and a chronic cough. Emphysema involves the destruction of the alveoli (air sacs) in the lungs, reducing their elasticity and causing air trapping.

- Asthma: Asthma is a chronic inflammatory condition of the airways that leads to recurrent episodes of wheezing, breathlessness, chest tightness, and coughing. During asthma attacks or exacerbations, the airways become even more constricted due to increased inflammation and bronchoconstriction.

- Bronchiectasis: Bronchiectasis is a condition characterized by the permanent dilation of the bronchial tubes due to chronic inflammation and infection. This leads to the accumulation of mucus, making it challenging to clear the airways and increasing the risk of recurrent infections.

- Cystic Fibrosis (CF): Cystic fibrosis is a genetic disorder that primarily affects the lungs and digestive system. It causes the production of thick and sticky mucus, leading to recurrent lung infections and progressive lung damage.

Here Airway Resistance plays a major role, More than the compliances in the lungs and thoracic cage. Resistance will be higher than usual and airway compliance will be lower. To maintain the same minute volume PEEP has to be increased.

The following values are approximated to have the described property as i was unable to find exact values of any of the mentioned diseases.

Lung Compliance	$= 0.1\ L/cmH_2O$
Thoracic Compliance	$= 0.1\ L/cmH_2O$
Airway Central Resistance	$= 20.0\ cmH_2O/(L/s)$
Airway Peripheral Resistance	$= 5\ cmH_2O/(L/s)$
Airway tissues Compliance	$= 0.001\ L/cmH_2O$
Breathing frequency	$= 15$ BPM
PEEP	$= 5\ cmH_2O$
Peek Pressure	$8\ cmH_2O$
I:E	1:2

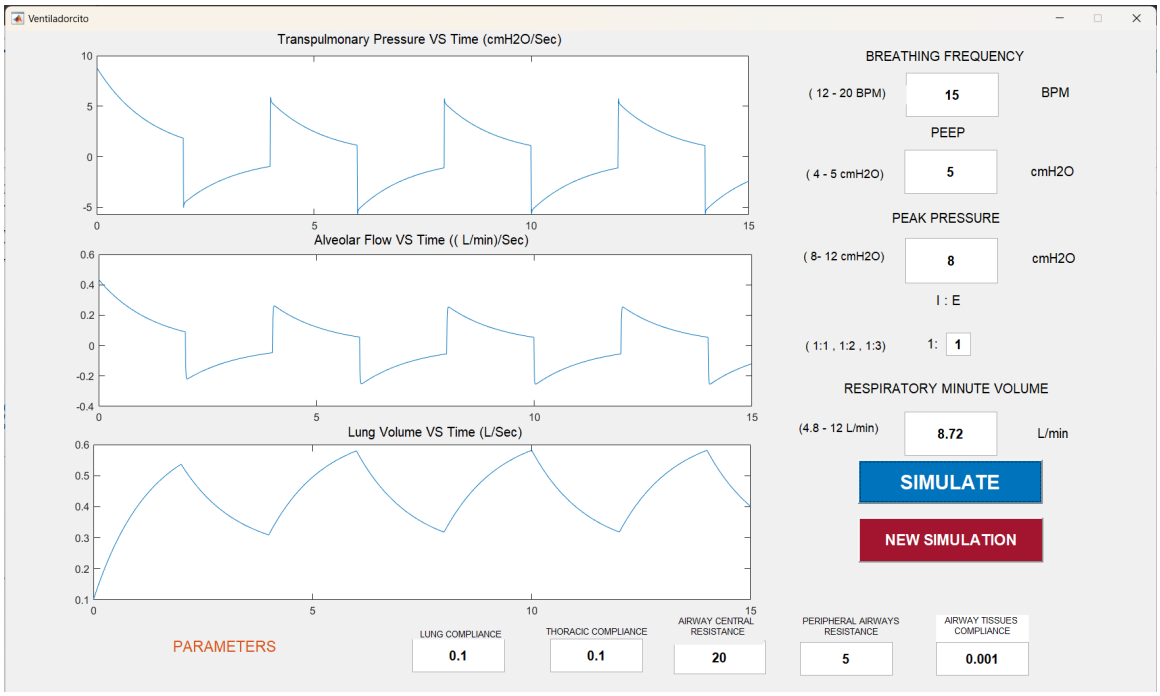


Figure 8: Ventiladorcito

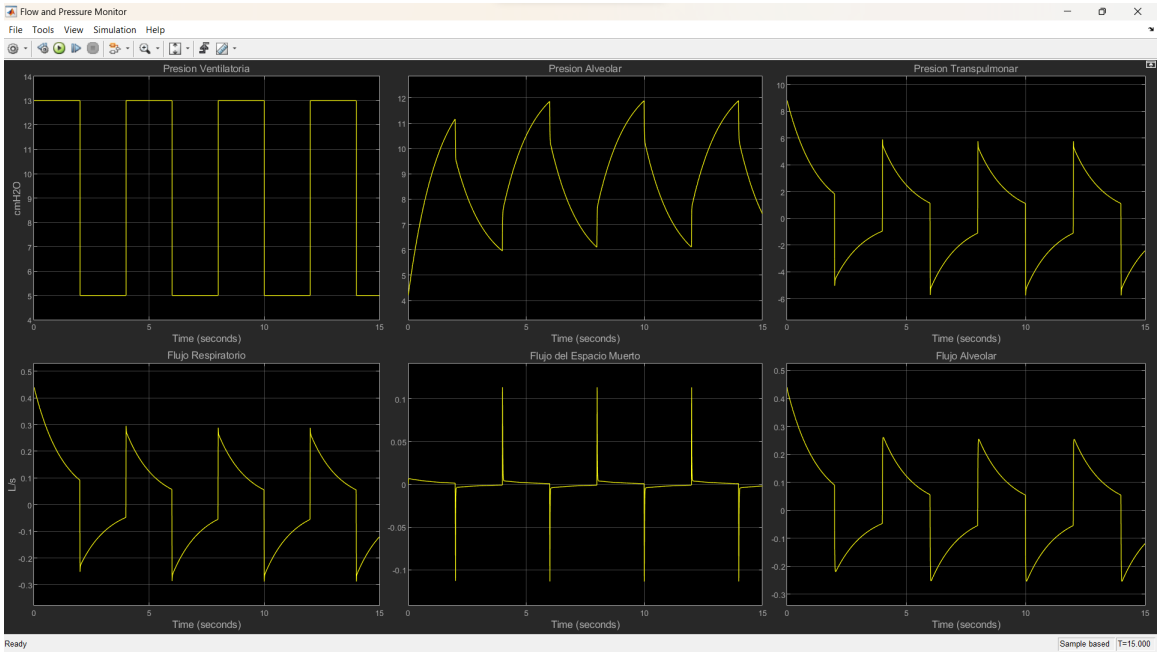


Figure 9: Flow and Pressure Monitor

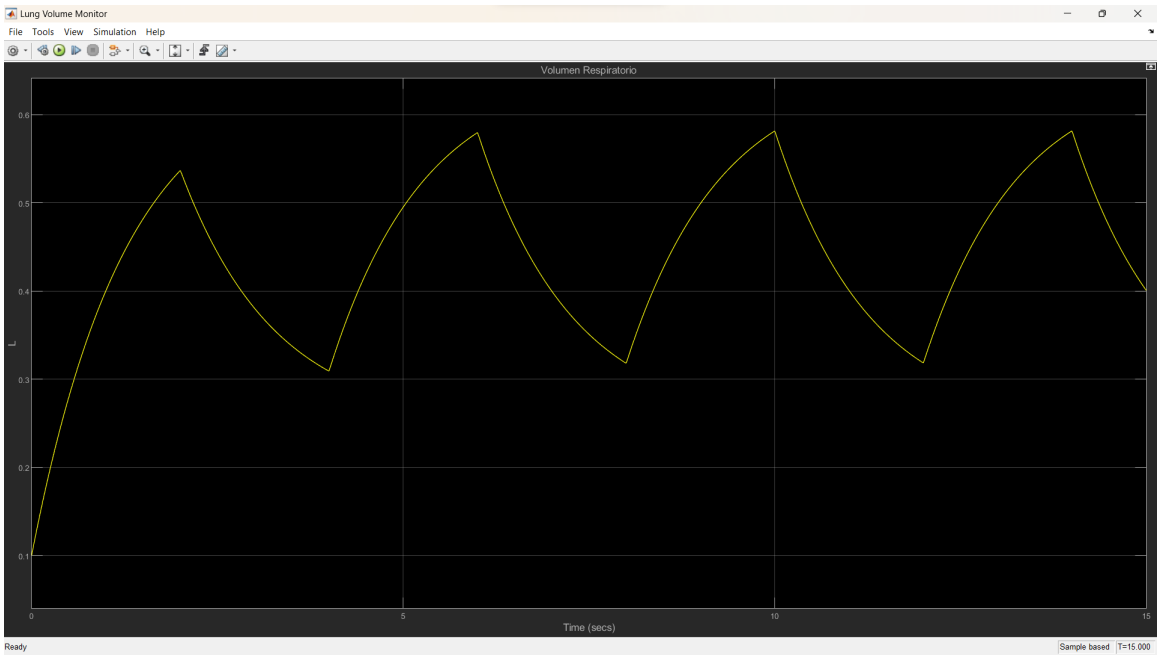


Figure 10: Lung Volume Monitor

Respiratory minute volume is in range for the patient.

4 Differences in minute ventilation for the same setting of the ventilator

MV(minute ventilation) of the patient can be different for several reasons, for example,

- Patient's health condition
- Patient's lung size
- Patient's breathing effort

- Ventilator setting etc.

We have to adjust the settings until the patient receives the required minute ventilation.

References

1. Simulation of Respiratory Mechanics on Simulink with GUI