

**UNIVERSITI TEKNOLOGI MARA**

**ENHANCING MECHANICAL  
VENTILATION MANAGEMENT  
THROUGH A MODIFIED TIME-  
VARYING ELASTANCE MODEL  
AND DEEP LEARNING MODEL  
FOR DETECTING ASYNCHRONY  
BREATHING IN ARDS PATIENTS**

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## ABSTRACT

Acute Respiratory Distress Syndrome (ARDS) is a severe condition caused by an inflammatory reaction in the lungs, resulting in fluid accumulation in the alveolar sacs, commonly observed in patients with respiratory failure. These ARDS patients require a treatment that can aid and support ARDS patients' recovery, which is through mechanical ventilation (MV) therapy for breathing support. Although MV effectively supports the breathing, however, during MV therapy, the MV management encounters few challenges, including addressing the asynchrony breathing (AB) resulting from spontaneous respiratory efforts during MV therapy. Thus, this study aims to optimise MV management for ARDS patients who are experiencing AB, by developing enhanced mathematical models and machine learning algorithms especially for patients that developed AB. Initially, this study proposed an extended time-varying elastance model along with the integration of negative elastance, as respiratory elastance, particularly those who modify their airway pressure and airflow due to spontaneous breathing efforts, thereby dynamically quantifying lung mechanics, which complicates the ventilation adjustments. In addition, this study also employed deep learning techniques to detect and classify AB patterns, leveraging one-dimensional and two-dimensional patient airway pressure data for real-time application. This study presents two classification methods, which a 2D convolutional neural network (CNN) methodology for classifying the type of airway pressure based on input images and 1D of patient airway pressure data as an input to the convolutional long short-term memory neural network (CNN-LSTM) with a classifier, which could significantly mitigate complexity and calculation, thereby enhancing accuracy. Results show that the developed extended time-varying elastance model, as well as the developed extended time-varying elastance integrated with negative elastance, proved highly reliable in estimating asynchrony events due to the spontaneous breathing effort across different ventilation modes, offering actionable insights for adjusting ventilator settings to minimise ventilator-induced lung injury (VILI). Meanwhile, for both classification methods using 2D CNN classification methods and 1D machine learning integrated with classifiers, demonstrated high accuracy in detecting AB, with integrated deep learning models with classifiers able to distinguish between normal breathing and AB types such as reverse triggering and premature cycling. Performance metrics, including k-fold cross-validation and confusion matrix analysis, highlighted robust model accuracy exceeding 98%. The extended mathematical modelling and integration of machine learning with classifiers provide a comprehensive framework for improving MV management. Real-time analysis of respiratory mechanics and AB patterns enables clinicians to fine-tune ventilator settings tailored to each patient's needs. In conclusion, this study advances MV therapy by offering precise, non-invasive tools for optimizing ventilation settings and managing AB. By supporting better decision-making and reducing clinical workload, these models pave the way for safer, more effective, and patient-centred respiratory support in intensive care settings.

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# CHAPTER 1

## INTRODUCTION

### 1.1 Research Background

The respiratory system comprises the organs of the human body that are responsible for breathing. The primary function of the respiratory system is to inhale oxygen and exhale carbon dioxide. The organs of the respiratory system include the nose and nasal cavity, mouth and oral cavity, sinuses, pharynx, larynx, trachea, bronchi, lungs, alveoli, and diaphragm, as illustrated in Figure 1.1. The main organ for the respiratory system is the lungs. The lungs are responsible for the exchange of gases (inhale oxygen and exhale carbon dioxide) during respiration.

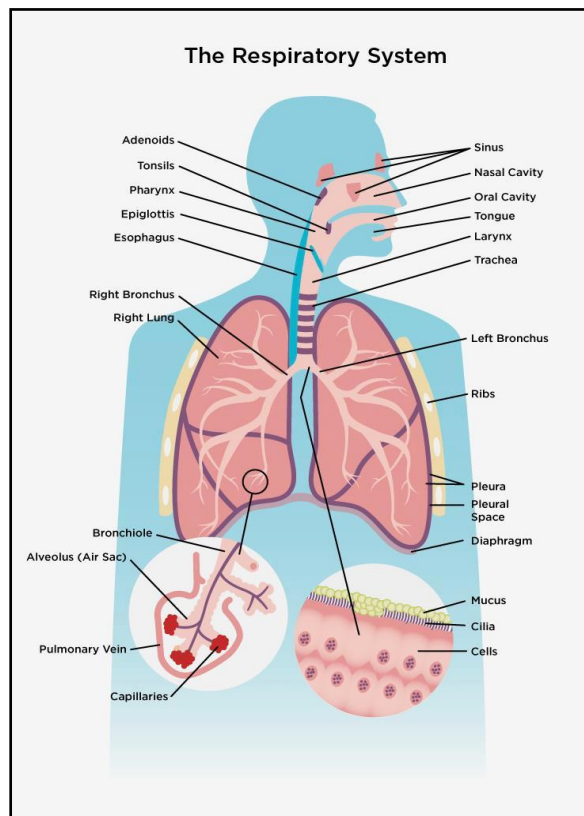


Figure 1.1 The human body's respiratory system [1]

Respiratory failure, on the other hand, can happen when the lungs can't perform their primary duties of blood oxygenation and removal of carbon dioxide. This respiratory failure may happen due to diseases that adversely affect the function of the