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GBIO0014 - In silico medicine
Project 2023-2024

Context:
ARDS (Acute Respiratory Distress Syndrome) is an inflammatory process that affects the lungs resulting in severe hypoxemia (low oxygen levels). It is a common cause of admission to intensive care units and is associated with high mortality rates.

The objective of the project is to characterize the pulmonary mechanics of both healthy lungs and lungs affected by ARDS using different models.

Data:

You will work on two different datasets including recordings of respiratory cycles with time (s), flow rate (l/s), pressure in the airways (cmH2O) and volume (l):
- Control Data ("Control.mat"): respiratory cycles in healthy pigs.
- ARDS Data ("Ards.mat"): respiratory cycles in pigs with ARDS.

Project:

1. For both the 'Control' data and 'ARDS' data,
    a. Represent a pressure-volume loop (x axis = pressure) and identify the inspiratory and expiratory phases. From the pressure-volume loops, calculate the work-of-breathing (work done to ventilate) and its 3 components: elastic work, resistive inspiratory work, and resistive expiratory work.
    b. Represent a flow-volume (x axis = volume) loop for and identify the inspiratory and expiratory phases, peak inspiratory flow and tidal volume.
    c. Analyze the influence of ARDS on these loops
2. Consider the single compartment model to describe the lung mechanics (Equation 1):

$$\mathbf{Paw = Ers \times V(t) + Rrs \times Q(t) + P0 \ (1)}$$

    a. Use a linear regression to estimate the respiratory elastance (Ers), the respiratory resistance (Rrs) and the offset pressure (P0) for each respiratory cycle.
    b. Identify these 3 parameters for both 'control' and the ARDS datasets. Parameters should be expressed as median [25^{th} - 75^{th} percentiles] (for each dataset).
    c. Describe the influence of ARDS on Ers and Rrs.
3. Consider a patient mechanically ventilated and whose respiratory system is modelled with the linear two-compartment model depicted in Figure 1. The patient is ventilated in pressure-control mode. This mode delivers a square pressure waveform: $p = p_{max}$ = 20 cmH2O during inspiration and p = 0 during expiration, the length of the expiratory phase is twice as long as the length of the inspiratory, the respiratory rate is 20 breaths per min, and the PEEP is 5 cmH2O.

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a. Create a 30-seconds pressure waveform P(t), with the same sampling frequency as the original data from point 1, corresponding to the pressure-control mode.
b. Using P(t) from point 3a, and the median values of elastance and resistance calculated at point 2b for the ‘control’ dataset, calculate the evolution of the input flow and volume. For these simulations, you will consider that the initial flow and volume are null and the resistance of the trachea Rc = 5 cmH2Os/l.
c. Calculate the evolution of pressure, flow and volume in each lung. The lungs are considered empty at t=0.
d. Compare and analyze the results obtained in 3b and 3c and the impact of ARDS on lung mechanics if the elastance and resistance of one of the lungs are those calculated at point 2b for the ‘ARDS’ dataset. Finally, consider that both lungs are affected by ARDS.

The report will be sent by email.
Deadline: 17 May 2024

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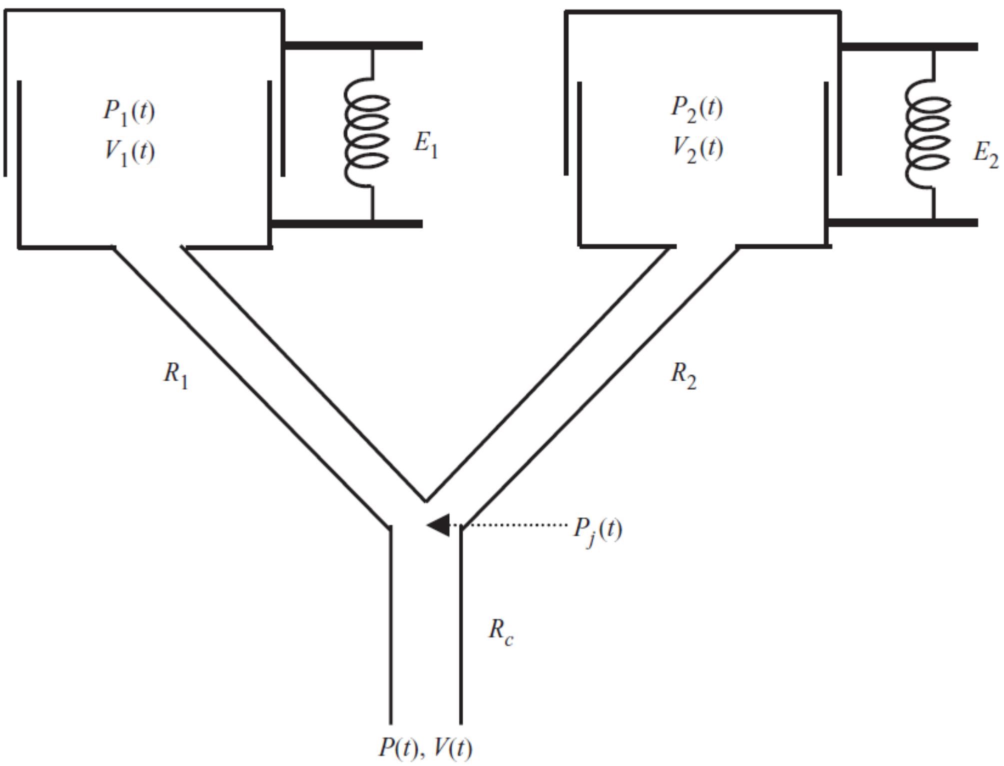

Fig 1: Two-compartment model

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