Physiological Modelling T11
Summer Semester 2022

Temporal Recruitment

Level: **Challenge**/ Demanding/ Difficult

Task: In the lectures you have learnt about recruitment of lung units and its effect on the compliance of the lung. An event driven model was introduced (Hickling model), that was able to simulate pressure-volume relations in an ARDS lung. The lung is divided into 30 layers, that open on different pressure levels. This opening process is either immediate when the pressure threshold is passed, or following a uniform distribution in a predefined pressure range (between Opmin and Opmax). In the literature it is reported that recruitment is temporal process i.e. is often not instantaneous, but delayed because the gas must remove fluid from a bronchiole before reaching the alveolus.
Thus, your task is to create a layered dynamic recruitment model, which opens Alveolar layers according to a Gaussian distribution instead of a uniform one.

Approach:

1. Implement a temporal recruitment process in a simple lung model (FOM), by substituting the constant compliance term with a pressure driven recruitment process (Hickling). Use a **volume controlled** mode (constant flow inspiration) for the simulation setup.
   Test your software to check if it produces reasonable results. Run your FOM simulation and the Hickling model separately before combining them. Document the test results.
2. Modify the "Hickling model" with a time dependent opening process, i.e. the opening of alveoli on a layer is not purely based on pressure but on the pressure-time integral. Just in case that pressure is long enough present, an opening of alveoli is enforced.
   a. Implement a mechanism to calculate and store for every layer the duration of effective pressure. Hint: please consider an auxiliary variable ("Open") which integrates the weighted pressure-difference of current airway pressure (P(t)) and critical pressure (P_crit = SP+TOP with the superimposed pressure (SP); threshold opening pressure (TOP) for a given layer).

      $$\frac{dOpen}{dt} = Const \cdot (P(t) - P_{crit}) \quad \text{if } P(t) > P_{crit} \quad (1)$$

      A unit of a layer opens, when this value reaches a predefined threshold, e.g. 1.
      Test this opening mechanism by "imposing" a sudden pressure increment and demonstrate how much time is required to reach the open threshold for all layers.
   b. Integrate this form of "opening" into a layered lung model according to Hickling's 30 Layers.
   c. Demonstrate its functionality by creating plots i.e. dynamic P/V curves for different PEEP steps, when PEEP is changed from 0mbar to 5 (10, 15, 20, 25) mbar and kept constant.

3. Implement a Gaussian probability distribution for every layer that determines the percentage of opening units with respect to the "Open"-Variable. This could be achieved in different ways, e.g. with varying P_crit values, and/or Const-values or directly with the Open-Threshold. Please describe some alternatives and discuss which one might be best to use. Create a concept and implement in Matlab. Test the effect of different standard deviations on the compliance vs pressure relation. What is the greatest variation in compliance, that can be provoked at a certain pressure level (in steady state) within the normal ventilation range (0-50mbar)?

4. All together: Combine your two solutions into an overall simulation that implements a dynamic lung model driven by a Gaussian opening distribution. Show that it is working in a reasonable way by simulating some inspiration curves (pressure and flow) for some selected parameter settings.

Final Report due July 1st.
In case of questions please arrange an appointment via email or pass by on Tuesday morning 09:45-11:15 at M0.03.