DESIGN AND IMPLEMENTATION OF THE MATHEMATICAL MODEL OF THE HUMAN RESPIRATORY SYSTEM BASED ON ITS ANATOMICAL STRUCTURE

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Introduction: Different effects of artificial ventilation can be observed when conventional ventilation (CV) or high frequency ventilation (HFV) are used. Unpredictable differences mainly in oxygenation, which have not been explained yet, can be observed in clinical practice. Many parameters can influence the oxygenation, but their effect is mostly impossible to study directly in the human body. Therefore, deriving a mathematical model of the respiratory system exactly corresponding with the reality can be the only possibility how to study influence of mechanical lung properties through the bronchial tree, distribution of tidal volume among generations of alveoli, etc. A unique modelling approach has been chosen in this study based on the respiratory system modelling according to its exact anatomical structure in this study and simulations using the model are used to describe unequal effects of both the ventilation modes upon various parameters characterising intrapulmonary conditions.

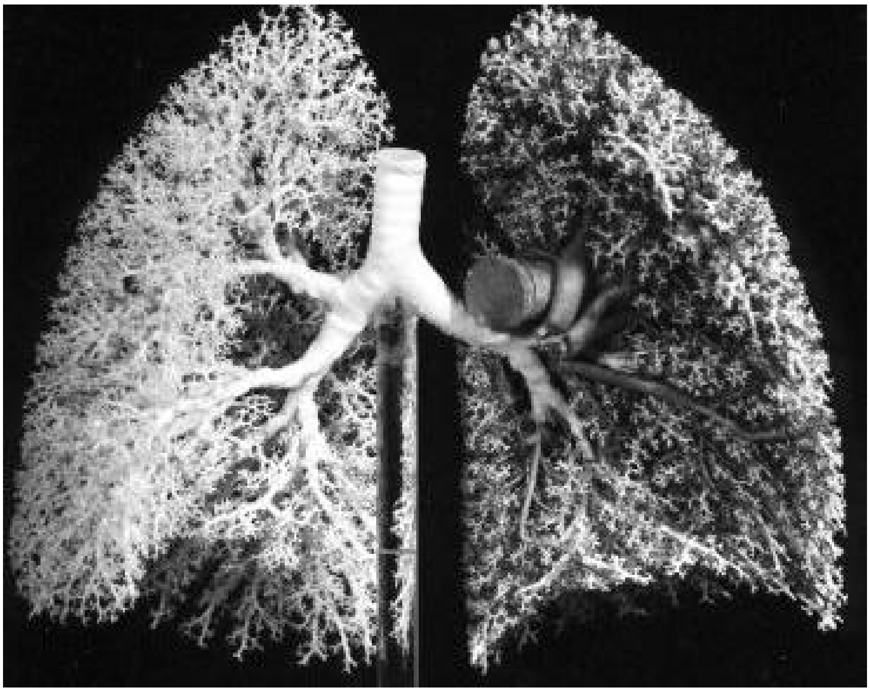

Fig. 1: Anatomical structure of the respiratory system. Reprinted from [4].

Methods: A mathematical model of the respiratory system has been developed as an electro-acoustic analogy [1] of the respiratory system respecting its exact anatomical structure. A very complex structure of the respiratory system can be seen on the left-hand side of figure 1. On the second half of the figure there are shown also the blood vessels. All individual airways are represented by short acoustic wave-guides with parameters computed using the common acoustic principles and published lung morphometry measurements [2, 3, 5]. Alveoli are represented by acoustic compliances computed from their dimensions [2, 3, 5] and overall lung compliance. The final model has 23 airway generations and employs 67 108 859 individual components. The structure of the model is shown in figure 2. The elements with index 1 represent the trachea. Other elements represent next generation of the airways. Each index of these elements determines generation of the airways.

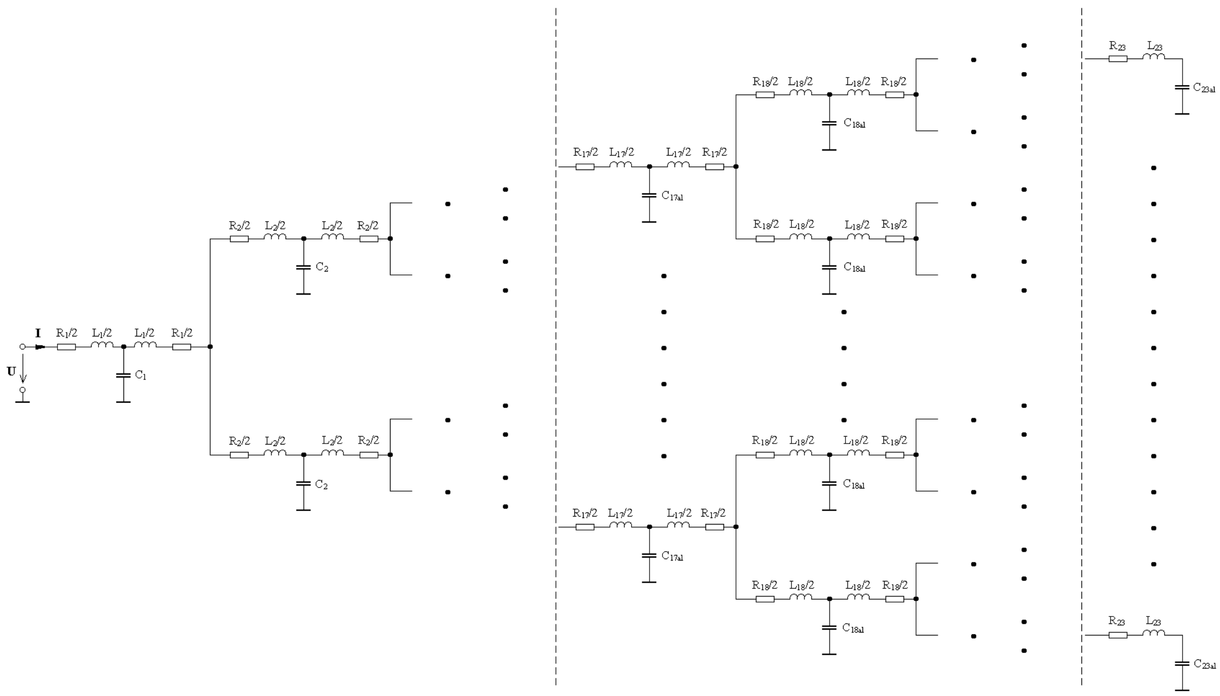

Fig. 2: Model of the respiratory system.

A special method has been developed so that such a complicated model could be used for simulations of the real situations. Ventilatory frequency of 0.25 Hz is considered for CV and 5 Hz for HFV. Distribution of tidal volume V_T and pressure amplitude among generations of bronchial tree, total lung impedance *(TLI)* and other variables are studied under various conditions by modelling.

The influence of respiratory mechanics [6, 7] upon the *TLI* was studied for frequencies that correspond with ventilatory frequencies used during CV and HFV. Dependence of *TLI* on the alveolar compliance is shown in figure 3. In figure 4 the effect of the airway resistance on the *TLI* is shown.

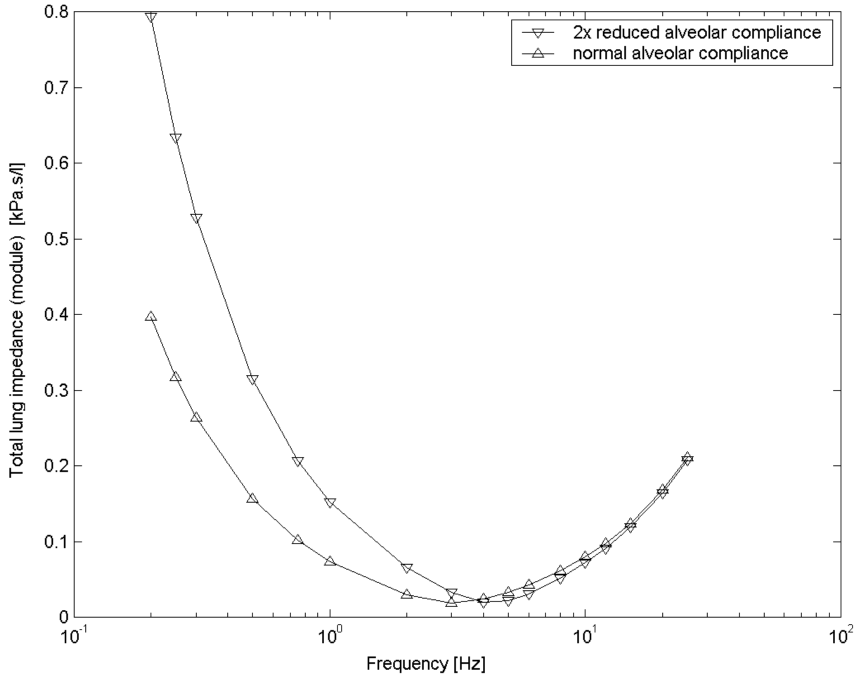

Fig. 3: Dependence of total lung impedance (TLI) upon ventilatory frequency and alveolar compliance changes.

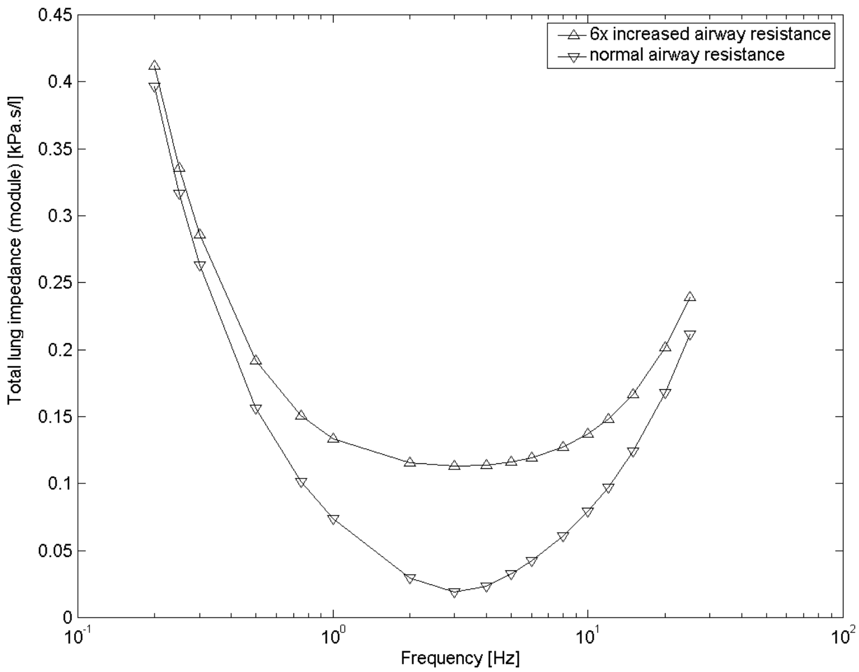

Fig. 4: Dependence of TLI upon ventilatory frequency and airway resistance changes.

Results: Changes of alveolar compliance have significant effect on *TLI* during CV while *TLI* changes during HFV are not essential (effect of airway inertances). Contribution of airway resistance changes is significant mainly during HFV. *TLI* is essential variable for pressure controlled ventilation modes. Distribution of V_T among individual generations is more or less independent on ventilatory frequency.

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