STUDY OF THE INTRAPULMONARY CONDITIONS USING A MATHEMATICAL MODEL OF THE HUMAN RESPIRATORY SYSTEM DURING ARTIFICIAL LUNG VENTILATION

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Abstract: An electro-acoustic analogy was used to develop the mathematical model of the respiratory system respecting its exact anatomical structure. Distribution of tidal volume and pressure amplitude among generations of bronchial tree, total lung impedance and other variables are studied under various conditions by modelling.

Introduction: Artificial lung ventilation is the most efficient method for treatment of acute respiratory failure. Despite the fact that artificial lung ventilation has been examined properly and new protective ventilatory modes have been introduced, there are still strong adverse effects of artificial ventilation upon patient's respiratory system. A quite new ventilatory strategy is called high frequency ventilation (HFV). HFV can be characterized by increased ventilatory frequency (up to 40 Hz) allowing a significant decrease in pressure amplitude and delivered tidal volume. Usage of the small pressure amplitudes in the airways and breathing with very low tidal volumes prevent the lungs from overdistension, barotrauma and volutrauma. These properties represent the most significant difference between HFV and conventional artificial lung ventilation (CV) and they identify unconventional ventilatory strategies. Different effects of artificial ventilation can be observed when conventional ventilation or high frequency ventilation is used. Many parameters can influence the oxygenation, but their effect is mostly impossible to study directly in the human body. Therefore, deriving 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. Simulations using the model are used to describe unequal effects of both conventional and high frequency ventilation modes upon various parameters characterizing intrapulmonary conditions.

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. The structure of the respiratory system is very complex and it is very difficult to describe this structure mathematically. 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, 4]. Alveoli are represented by acoustic compliances computed from their dimensions [2, 3, 4] 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 1. 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.

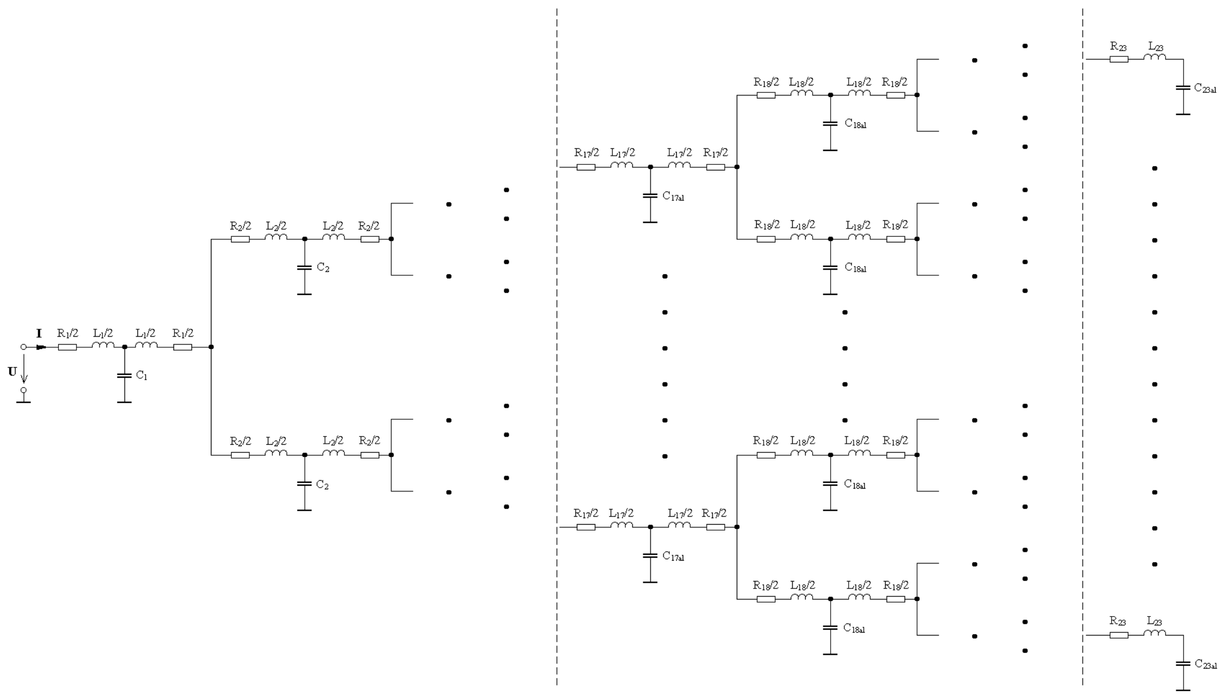

Fig. 1: Model of the respiratory system.

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 upon the *TLI* [5, 6] was studied for frequencies that correspond with ventilatory frequencies used during CV and HFV.

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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