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SHORT COMMUNICATION

EFFECTS OF CONSTRICTION IN A MECHANICAL MODEL OF LUNG PARENCHYMA

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Abstract: The demands on materials' properties, for medical purposes, largely depend on the site of application and the function it has to restore. Ideally a replacement material should mimic the living tissue from a mechanical, chemical, biological, and functional point of view. The estimation of the mechanical characteristics of blood vessel walls, the values of modulus of elasticity and the coefficient of transversal strain serve to determine some aspects of reconstruction of blood vessels. The tissue growth, the blood clotting and the affecting blood elements are influenced by surface energy. In this study, we address the possibility to investigate the mechanical properties of the airways in a simulation study of the human lungs.

Keywords: *biomaterials, biomimetic, lung parenchyma, mechanical model, tissue substitute*

INTRODUCTION

The development of materials for any replacement application should be based on the thorough understanding of the structure to be substituted. This is true in many fields, but particularly relevant in substitution and regeneration medicine. The fractal structure of the lung's geometry is a useful property to describe such complex system in a simple, elegant manner [1].

In this line of thought, we employ our previous results to simulate changes in the airway constriction and heterogeneous parameters. In this simulation study we assess variations in airway mechanical properties using a mechanical equivalent of the respiratory structure. The simulation is based on a simplified model of the respiratory duct, but taking into account the significant information on human lung morphology: airway radius, length, thickness and cartilage over soft tissue percent [1 – 3].

EXPERIMENTAL METHODS

Building anatomical models for low frequency analysis of the respiratory input impedance is useful when evaluating the airway properties at ventilation frequencies up to 10Hz. In this study, frequency-domain analysis is used based on a mechanical analogy. By means of electro-mechanical analogy, the voltage represents the force and the current represent the velocity of the tissue motion [3].

RESULTS AND DISCUSSION

A fractional-order (FO) model has been proposed to model the simulated respiratory impedance. The model proved to have an efficient estimation in terms of minimal errors and minimal number of parameters. The fractional order denotes fully viscous element for order 1 and fully elastic element for order 0. The structure of the FO model is given as:

$$Z(j\omega) = R + L \cdot (j\omega)^{\alpha} + \frac{1}{C \cdot (j\omega)^{\beta}} \tag{1}$$

with:

$0 \leq \alpha \leq 1$;

$0 \leq \beta \leq 1$;

R – the resistance (kPa·s/L);

L – the inertance (kPa·s²/L);

C – the compliance (L/kPa);

$j^2 = -1$;

ω – the angular frequency (rad/s).

Although the respiratory system can be indeed well approximated with such a model, the relationship between its physiological mechanical properties and fractional operators is not totally understood. The reason for the successful characterization of input respiratory impedance with this model is that the real part is not frequency-independent, as in case of integer-order models. The objective of the use of fractional-order modeling in this study is twofold:

i) to analyze the correlation between the variation of the fractional-orders with the variation of the airway properties;

ii) to analyze if the model parameters are sensitive to changes in broncho-constriction and heterogeneity.

Further on, the variations in model parameters with broncho-constriction and airway heterogeneity are illustrated by variations in the identified resistance [4].

We have simulated changes in the first 5 airway generations of the respiratory tree in terms of constriction $\kappa = 0,\ 20,\ 40,\ 60$, and in terms of heterogeneity $CV = 0,\ 10,\ 20,\ 40$. Variations in the κ and CV parameters did not influence the identified values of the lumped FO model for compliance, neither its corresponding order.

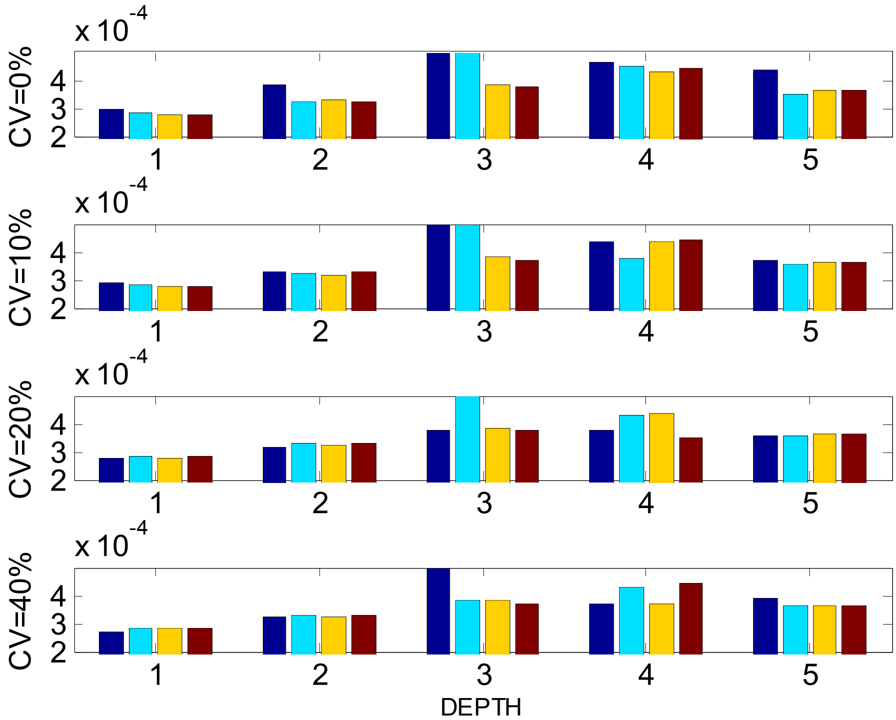

Figure 1. *Identified Resistance parameter values for each depth, from homogeneous (CV = 0%) to highly heterogeneous (CV = 40%) heterogeneity levels. Each value per depth in each heterogeneity level denotes four constriction levels from left to right: 0%, 20%, 40% and 60%.*

CONCLUSION

In this study, the effect of changing airway length, radius, wall thickness and tissue cartilage percent on a fractional order model parameter has been investigated. As a result, the fractional order model parameters seem to be sensitive to changes of broncho-constriction in the airway duct and various levels of heterogeneity.

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