Reconciling the Mechanical Properties of Lung Tissue at the Meso- and Microscale

Authors: Elizabeth Dimbath*[1], Stephanie George[1], PhD, Ali Vahdati[1], PhD
[1]Department of Engineering, East Carolina University, Greenville, NC 27858

Introduction: The emergent mesoscale mechanical properties of the lung tissue are dependent on the microscale properties of the alveolar wall components and the surface tension. Currently, microscale mechanical testing approaches for lung tissue rely on techniques such as atomic force microscopy (AFM), to estimate septal wall properties, whereas uniaxial tension is commonly used for mesoscale measurements. However, there are many discrepancies in reported stiffness values of lung tissue, even among studies performed at a similar length scale, in part due to different experimental setups, specimen size, and test techniques. Therefore, our aim is to use computational modeling to reconcile the lung tissue mechanical properties measured using different techniques at different length scales.

Materials and Methods: A mesoscale finite element (FE) model composed of a network of hexagonal geometries representing individual alveoli was constructed in COMSOL Multiphysics 5.6 (COMSOL Inc, MA, USA). Uniaxial tensile tests were simulated using FE analysis to compare the results of two microscale studies based on AFM [1,2] to two studies of lung tissue strips at mesoscale [3,4]. Mechanical properties from microscale studies were applied to the mesoscale models with model dimensions of 5 x 5 x 0.4 mm corresponding to specimens used by [4] and with dimensions 7 x 2.2 x 1.2 mm for comparison with [3]. Then, emergent properties from the computational model were compared to the two sets of experimental data on lung tissue strips at the mesoscale [3,4].

Results and Discussion: The studies conducted at micro- as well as mesoscale, accounted only for mechanical properties of alveolar tissues and not surface tension. In comparison to the data from mesoscale studies, emergent behavior based on microscale studies showed some similarity to mesoscale behavior in specific strain ranges as seen in Figure 1. At lower strains, the mechanical properties from AFM studies [1,2] resulted in underestimation of stiffness compared to the mesoscale data with strain-stiffening occurring at larger strains in both meso- and

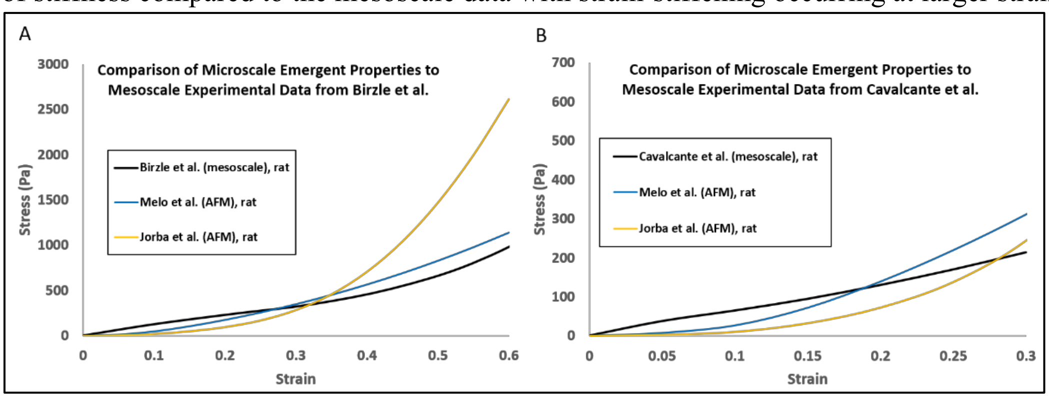

Figure 1. Stress-strain curve comparison of modeling results to experimental datasets. A. Comparison to data from [3]. B. Comparison to data from [4].

Conclusion: Many studies on determining lung mechanical properties at the micro and mesoscales have reported a wide range of moduli for lung tissue. Our study shows that micro- and mesoscale mechanical testing data on lung tissue can be reasonably reconciled using computational modeling. Additionally, our analysis showed that microscale mechanical testing studies tended to underestimate the lung tissue stiffness at lower strains compared to the mesoscale studies. In using stiffness values for FE modeling of the lung tissue, it is essential to consider the experimental setup, pre-loading, and length and time scales of the mechanical tests performed to obtain relevant and accurate stiffness values.

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References: 1. Melo E. *Tissue Eng. Part C-Methods.* 2014, 20. 412-422. **2.** Jorba I. *Acta Biomater.* 2019, 92. 265-276. **3.** Birzle A.M. *J. Mech. Behav. Biomed. Mater.* 2019, 94. 126-143. **4.** Cavalcante F. *J Appl Physiol.* 2005, 98. 672-679.