Fractional Poroviscoelastic Modeling of Sound and Vibration in the Lungs

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ABSTRACT: Noninvasive measurement of mechanical wave motion (sound and vibration) in the lungs may be of diagnostic value, as it can provide information about the mechanical properties of the lungs, which in turn are affected by disease and injury. In this study, two theoretical models of the vibro-acoustic behavior of the lung parenchyma are compared: (1) a Biot theory of poroviscoelasticity and (2) a simplified "bubble swarm" model for compression wave behavior. A fractional derivative formulation of viscoelasticity is integrated into both models. A measurable "slow" compression wave speed predicted by the Biot theory formulation agrees well with the bubble swarm theory. Biot theory also predicts a fast compression wave and a shear wave. The relative contributions of all three wave types are assessed for several different scenarios theoretically, computationally and experimentally. This study suggests that, if only the compression wave motion of the soft tissue of the lung parenchyma is of interest, then the bubble swarm theory may be sufficient. Indeed, the bubble swarm theory can be implemented in a solid mechanics model to also predict the shear wave motion of the tissue. This approach is simpler than implementing Biot theory but will have some deficiencies.
[Financial support of the National Institutes of Health (Grant Nos. EB012142 and EB007537)) is acknowledged.]