The Multiscale Audible Human Project

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Mechanical wave motion (acoustics) over multiple temporal and spatial scales pervades existing and emerging diagnostic and therapeutic medical technology for every organ and region in the body. Diagnostic approaches span from auscultation (body sound analysis) to emerging dynamic elastography methods based on magnetic resonance, ultrasound or photonics for quantitatively imaging mechanical properties. Therapeutic examples include acoustic removal of excess airway secretions to accelerated (soft and hard) tissue repair via acoustic stimulation from hertz to millions of hertz. *Further advances in diagnostic and therapeutic capability are hampered by our limited fundamental understanding of acoustic wave phenomena – reflection, scattering, absorption – in the complex heterogeneous anisotropic medium that is the human body.* Nowhere else is this more evident than in the lungs, the most acoustically complex region where different pathological conditions lead to changes that uniquely alter acoustic behavior over multiple scales, providing a rich but woefully untapped source of noninvasively obtainable disease biomarkers and therapeutic possibilities. Moreover, the lungs are especially challenging for conventional medical imaging approaches based on ultrasound, magnetic resonance or ionizing radiation; consequently, many diseases of the lung have high morbidity and mortality.

The purpose of the *Audible Human Project (AHP)* (EB012142) has been to develop a computer simulation model of sound propagation in the human body to enable advances in therapy and diagnostics, as well as medical education. The AHP also seeks to accelerate the translational R&D process by creating *in silico* acoustic animal models that could replace the need for some live animal studies. However, as acoustic-based methods under development are affected by the interaction of physiological changes at many scales, the ability to computationally simulate their behavior drives the need for a *multiscale version of the AHP*, extending to the cellular spatial range and incorporating nonlinearity to account for mechanical strain of larger (multiscale in) amplitude with hysteretic behavior.

The goal of the *Multiscale Audible Human Project (MAHP)* is to implement multiscale simulation and visualization capability into the AHP. Initial studies have been focused on the subglottal respiratory airway tree, from the trachea to the alveoli, a multiscale structure within the lungs that undergoes geometric and mechanical property changes at different scales that may uniquely correlate with specific obstructive and restrictive pulmonary pathologies.

We present recent modeling and simulation results of acoustic wave propagation through comprehensive and realistic airway trees that are "grown" from base tree structures acquired from CT images, courtesy of C-L Lin – U Iowa, using a fractal airway based growth algorithm adapted from M Tawhai – U Auckland. These are merged with our modified 1D acoustic waveguide model. Shown below are the acoustic pressure and resulting airway wall radial velocity for a human airway tree resulting from sound introduction at the top of the trachea.

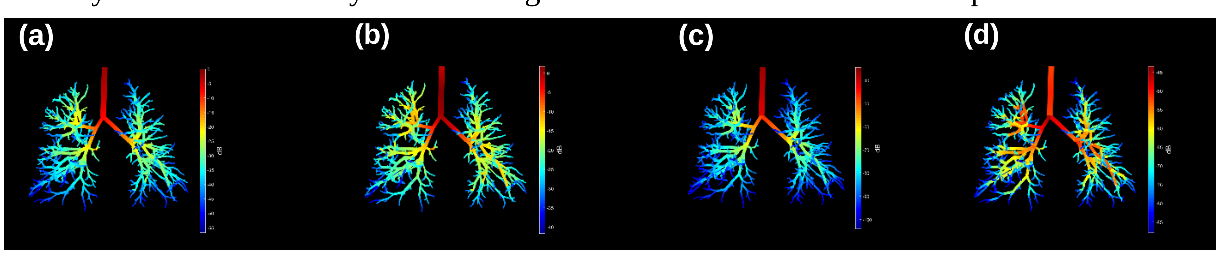

Figure 1. a and b: acoustic pressure for 200 and 800 Hz, respectively. **c and d**: airway wall radial velocity calculated for 200 and 800 Hz, respectively. Both are calculated in MATLAB via a modified 1D waveguide model. Values are normalized in dB.