ABSTRACT

Oscillometry (OS) is commonly performed by actuators that are heavy and bulky. In this thesis I designed and simulated a new single frequency OS system. This novel design used a piezoelectric bimorph actuator on resonance. To predict the performance, a dynamic model was simulated that included realistic respiratory impedance loads, and realistic recorded breathing noise. Model performance was also validated in a scaled prototype device. We found that while breathing noise substantially lowered SNR, the model could produce sufficient pressure and flows for acceptable SNR and accuracy. Together the results of the simulations and the scaled prototype indicated that this design is a feasible approach to develop an accurate lightweight, portable, single-frequency OS device.

Tracking the within-breathe impedance of the lung has gained attention among researchers because it is believed that it contains important information regarding the health of the lung. However, to date, there are very few studies that address the accuracy of estimating time-varying impedance. In this thesis we analytically and computationally developed a time-frequency transfer function that demonstrated increasing error with increasing breathing rate. Then we evaluated the accuracy of using short-time Fourier transform (STFT) methods in tracking time-varying impedance in simulations of a sample population (children). As expected however, these errors were much higher than noise-free simulations. Results indicated that current methods can track the impedance versus time reasonably accurately, but at high breathing rates, errors may be unacceptable.

It is established that resistance exhibits a pronounced frequency dependence that is increased in obstructive disease. Similarly, and thought to be unrelated, variations in reactance are also increased in COPD. By analyzing the equation of motion in the time-domain with time-varying resistance and elastance we found and proved that variations in elastance surprisingly influence the frequency dependence of resistance. This relationship was demonstrated again by the same time-frequency transfer function presented previously. Although this effect was small in the OS frequency range it was substantial at breathing frequencies. This is important as it provides a novel mechanism for frequency dependence of resistance, indistinguishable from OS methods alone, in addition to tissue viscoelasticity and heterogeneity of the lung.