THE SUMMARY OF Ph. D. DISSERTATION

Major Physics		SERA Toshihiro

Title

Localized compliance of airways, applied to respiratory flow of patient with obstructive airway diseases.

Abstract

The airway compliance is very important factor in pulmonary dynamics as well as in clinical application. This thesis has focused on the localized compliance of airway, especially trachea and small airways, and applied to respiratory flow of patient.

A trachea primarily consists of two different types of tissues: cartilage rings and smooth muscle. Cartilage rings form horseshoe-shaped structures in the cross-section and are stiffer than tracheal smooth muscles. Young's moduli of cartilage rings and of smooth muscle by using pig trachea were estimated using the linear relationship between the transmural pressure and the deflections. Each value was 5.8 ± 2.9 MPa and 0.65 ± 0.32 MPa, respectively.

Respiratory diseases mainly occur at small airways, however the airways are not visualized under the physiological condition. To visualize the three-dimensional structure of the small airways without dehydration and fixation, a two-step method was developed: to visualize small airways in detail by staining the lung tissue with a radiopaque solution and visualizing the tissue with a cone-beam microfocal X-ray CT system. This method is the first reported method that yields faithful high-resolution images of soft tissue geometry without fixation.

Using novel method, the morphometrical changes of the same small airways were analyzed and the localized compliance was evaluated. For the smaller airways, the diameter was 36% larger at end tidal inspiration (TV) and 89% larger at total lung capacity (TLC) (length was 18% larger at TV and 43% at TLC) compared with the values at functional residual capacity. The diameter did not behave linearly with $(\textit{lung volume})^{1/3}$. With increasing lung pressure, the diameter changed dramatically at a particular pressure during both inflation and deflation. The percentage of airway volume did not behave linearly with that of lung volume. Smaller airways were generally more compliant than the larger airways and exhibited hysteresis in their diameter behavior.

To investigate the effects of tracheal compliance on respiratory flow and, the flow fields in a mechanical realistic tracheostenosis model was clarified by using laser-Doppler velocimeter measurements. Spatial variation of wall distensibility was achieved in the model by varying the wall thickness based on the elastic modulus. Localized variation in wall distensibility influenced the flow in an airway, and turbulence production rate decreased faster at the more compliant wall. Turbulence intensity during expiratory flow was 2.1 times greater than that during inspiratory flow.

Airways deformed remarkably during respiration. The localized compliance will open the way to new research of the pulmonary dynamics.