Small Airway Deformation of Healthy Mice during Quasi-static Lung Inflation

Airway consists of a number of various compliant tubes from the trachea to alveoli, and the airway geometry deforms markedly during respiration. Respiratory diseases occur most frequently at small airways and alveoli, and the condition of small airways and alveoli has important physiological and clinical implications [1]. In many respiratory diseases, significant compliance abnormalities mainly occur in localized regions of bronchi and bronchioles, and thus localized or microscopic conditions of small airways must be identified by high resolution observations. Localized deformations reflect restricted regions in which small airways are embedded into the parenchyma and thorax (Fig. 1). In this study, to determine localized morphometric deformations (diameter (*D*) and length (*L*)) in microscopic regions of airways, such as small airways and alveoli, during respiration, we visualized the same airways of the same lung at functional residual capacity (FRC) and total lung capacity (TLC) during quasi-static inflation process [2].

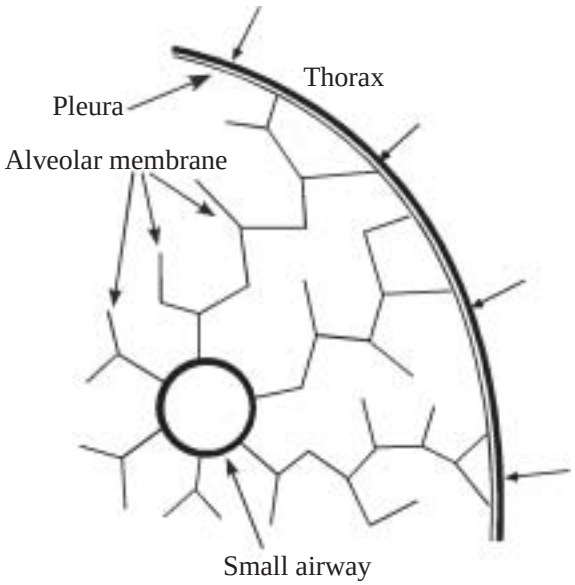
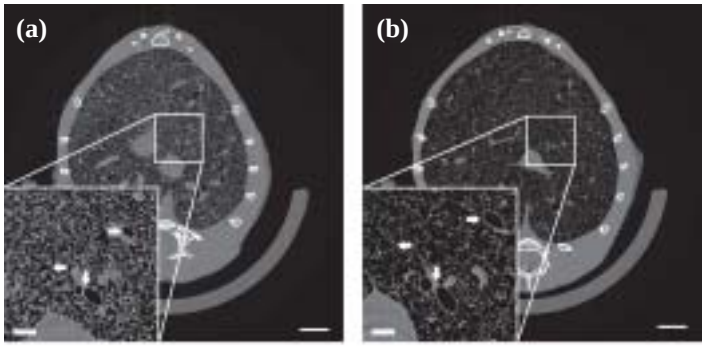


Fig. 1. Schematic model of small airways and alveoli in thorax.

The synchrotron radiation CT system was constructed at beamline **BL20B2**. The X-ray energy was 20 keV. To reconstruct CT images by the convolution back projection method, a series of projections were acquired at 1500 rotational positions around 180º in 7 ~ 15 min. The pixel size was 11.8 μm and the slice pitch was equal to the pixel size. A euthanized healthy mouse (C3H/HeJ, 9 weeks) was mounted on the rotation stage. To analyze the morphometric deformation of the same airway networks, the same branching networks were visualized at FRC and TLC during quasi-static inflation. FRC was defined as the lung volume at euthanasia, and lung volume could be externally regulated using a syringe connected to the trachea. The volume of TLC was defined as the sum of FRC + 800 μL [3]. We approximated the airway as a cylinder network, and the length (*L*) and diameter (*D*) of airway segments were determined by 3D thinning algorithm [2]. The fractions of increases in *L* and *D* (δ_L and δ_D) were normalized by FRC.

Figure 2 shows representative CT images and 3D volumes at FRC and TLC. At TLC, the airspace clearly increased and the airway geometry deformed markedly. δ_D and δ_L were presented as functions of the original diameter at FRC (Fig. 3). As the diameter at FRC decreased, δ_D increased. On the other hand, δ_L was not affected by the diameter at FRC. Then, the airway segments of all animals were classified into four groups using a diameter-based technique [4]: diameter ranges were FRC < 200 μm, 200 ~ 300 μm, 300 ~ 400 μm, and > 400 μm. δ_D and δ_L were 0.688 ± 0.026 and 0.295 ± 0.023 (average ± S.E.) for the smaller airways group (*D* at FRC < 200 μm), and 0.452 ± 0.017 and 0.229 ± 0.034 for the larger airways group (*D* at FRC > 400 μm), respectively. δ_D was larger than δ_L for all groups. Previously, Wang *et al.* [5] reported that the membrane was stiffer in the longitudinal than in the circumferential direction of the airway. To explain these differences, they histopathologically analyzed the morphometric structures of airway fibers and reported that the elastic fibers were mainly in the longitudinal direction, in agreement with the present results.

In conclusion, our study is the first to evaluate the localized morphometric deformation of small airways.



The airway diameter and the length of smaller airways (D < 200 μm) were respectively 68.8 % and 29.5 % larger at TLC than at FRC; in particular, the diameter was higher for smaller airways. Our results show that not all airways deform in the same manner.

Fig. 2. Representative CT images and 3D volumes at FRC (**a** and **c**) and TLC (**b** and **d**). Bars in normal images are 2 cm and those in zoomed images are 500 μm. Arrows with the same directions (**a** and **b**) and (**c** and **d**) indicate the same airways.

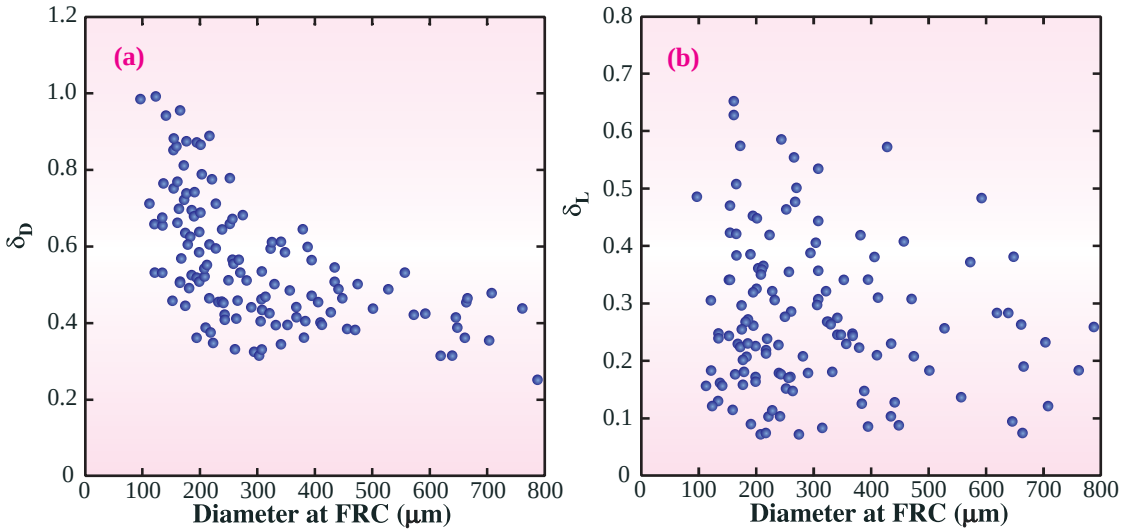


Fig. 3. Morphometric deformations ((**a**)δ_D and (**b**) δ_L) as functions of diameter at FRC.

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References

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