2D and 3D Visualization of Peripheral Lung Structure by Synchrotron Radiation CT

In many chronic lung diseases, the remodeling of the peripheral lung structure affecting peripheral ventilation often causes chronic respiratory failure. To precisely understand lung morphology and function, it is necessary to accurately visualize details of lung architecture. We demonstrated a new technique of 2D and 3D visualization the peripheral lung structure using isotropic volume data obtained by synchrotron radiation CT (SRCT) [1,3,4].

Lung specimens with pulmonary fibrosis and emphysema, and those without pulmonary diseases (normal) were obtained at autopsy, and were inflated and fixed. Each specimen was cut into a cylindrical shape of 6 mm diameter and 20 mm height. Projection images (360) of a specimen were captured using the SRCT system constructed at beamline **BL20B2** led from the source of synchrotron radiation. 2D SRCT images were reconstructed using these projection images on a workstation. Isotropic volume data with 12 μm voxel size were provided, stacked with 815 axial images of SRCT. 3D microstructures were obtained by automatic segmentation and combination of the surface and volume-rendering display technique on the workstation. For the 3D modeling of peripheral airflow, each point within the peripheral airway and airspace was assigned two values, one was the distance from the starting point, and other was the distance from the nearest airspace boundary. With these assigned values, the 3D model of air flow was demonstrated in the animation form.

SRCT images were correlated with the corresponding histopathologic images, point-by-point. SRCT demonstrated an approximately 10 μm area with clearly visualization of the alveolar wall, which was composed of two air-blood barriers of 0.5 μm thickness and a capillary of at least 8.6 μm diameter (Fig. 1) [2]. SRCT also demonstrated well the pathologic features. Each finding regarding various disease processes on SRCT images well correlated with histopathologic findings on microscopic images (Fig. 2) [3]. On the other hand, the 3D model of the peripheral lung structure could represent well the normal and pathologic lung structures (Fig. 3) [4]. In pulmonary fibrosis, the peripheral volume of airspace and beyond the respiratory bronchiole decreased compared with that in the normal model using animation. On the other hand, in emphysema, the volume increased compared with that in the normal model with animation. In both pathologic models, the difference in peripheral ventilation could be demonstrated clearly compared with that in the normal model.

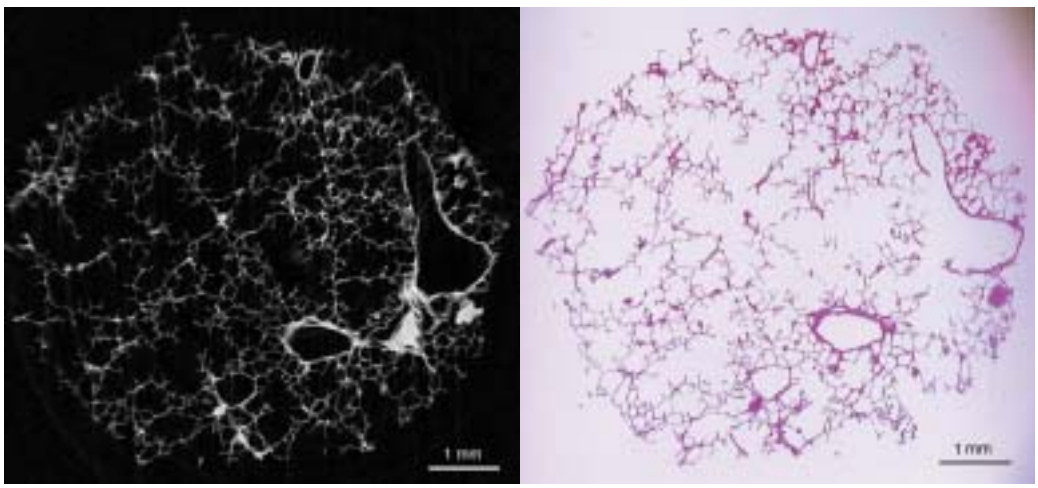

Fig. 1. Comparison between SRCT and microscopy images with normal human lung specimen. Synchrotron radiation CT image **(a)** with pixel resolution and thickness of 12 μm×12 μm, and 12 μm, respectively. Optical microscopy image **(b)** of a 6 to 12-μm-thick histologic section, which was stained with hematoxylin-eosin (original magnification, ×12.5). In the two figures, the scale bar corresponds to 1 mm.

In conclusion, the 2D and 3D analyses of the human peripheral lung structure by SRCT can provide important morphologic, physiologic, and pathologic information of the peripheral respiratory system. Currently, we cannot apply SRCT to patients in a clinical setting; however, important morphologic, pathophysiologic studies can be carried out using this ultrahigh resolution CT.

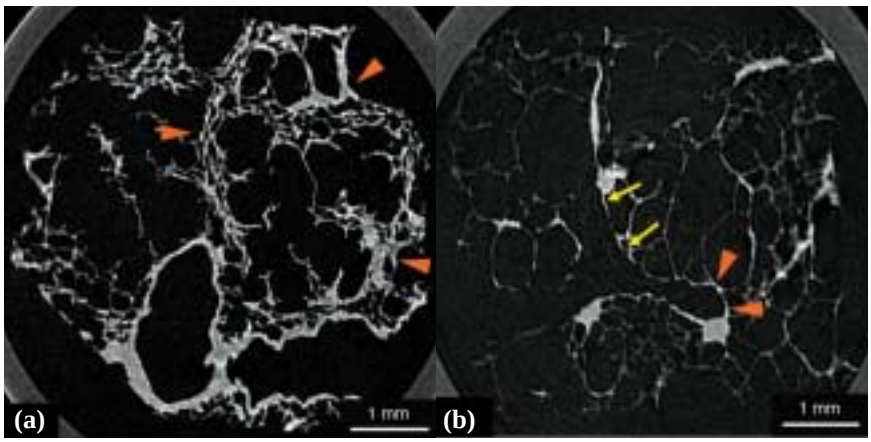

Fig. 2. SRCT images of pathologic lung specimen. SRCT images of pulmonary fibrosis **(a)** and emphysema **(b)**, with pixel resolution and thickness of 12 μm×12 μm, and 12 μm, respectively. For pulmonary fibrosis **(a)**, the dilatation of peripheral airspace due to interstitial fibrosis (arrowhead) can be observed clearly. SRCT can demonstrate the remodeling of the peripheral structure caused by interstitial fibrosis. For emphysema **(b)**, the peripheral airways and airspaces beyond the respiratory bronchiole (arrow) are dilated and destroyed. On the other hand, the terminal bronchiole in diseased specimens is narrower than that in the normal lung. SRCT also can demonstrate the pathologic features of emphysema on the microscopic order.

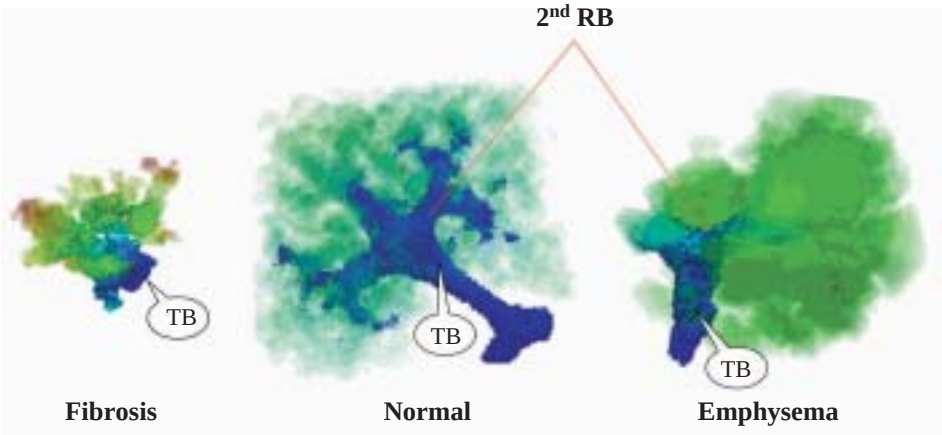

Fig. 3. Comparison of 3D models of the peripheral lung structure. These three models are adjusted to almost the same scale. Airflow is displayed with surface rendering (blue), when inspired air spreads into the bronchiole. Air diffusion is displayed with volume rendering (green), when inspired air spreads by diffusion in the more peripheral airspace. RB = respiratory bronchiole; TB = (most distal) terminal bronchiole.

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