Virtual Bronchoscopic Navigation

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KEYWORDS

- Virtual bronchoscopy
- Lung neoplasms and solitary pulmonary nodule/diagnosis
- Transbronchial biopsy • Three-dimensional imaging
- Endobronchial ultrasonography • User-computer interface

In recent years, solitary peripheral pulmonary lesions are being encountered more frequently because of the widespread use of CT scanning.[1] For the diagnosis of these lesions, bronchoscopy is routinely considered because it is safe and minimally invasive. However, its overall diagnostic yield is inadequate. The guidelines of the American College of Chest Physicians (ACCP) in 2007 showed a diagnostic yield of 57% for all lesions and 34% for lesions less than 2 cm in diameter.[2] The lesion-associated factors affecting the transbronchial diagnosis of solitary peripheral pulmonary lesions includes the lesion size,[3,4] its location,[3] the presence/absence of bronchial involvement,[5] and its malignant/benign status.[4] The bronchoscopist-associated factors include the apparatuses used and the bronchoscopist's skills and experience.[6]

At present, bronchoscopy for peripheral pulmonary lesions is performed using a bronchoscope with an external diameter of approximately 5 to 6 mm under x-ray fluoroscopy. Bronchoscopists mentally reconstruct the three-dimensional (3D) bronchial arrangement based on two-dimensional (2D) planar axial slices of CT, performed before the procedure, and select a bronchial path. A major problem with this method is difficulty in the guidance for the bronchoscope and its accessories. Bronchial path selection during the examination and at the same time maintaining the position of the bronchoscope along with its accessories in desired location under fluoroscopic guidance require time and skills. In addition, because the range of bronchoscope advancement is limited to around the subsegmental branches, biopsy instruments must be guided by fluoroscopy for a long distance from these proximal branches to the peripheral lesion. Therefore, the diagnostic yield depends on the bronchoscopist's experience and skill.[6]

To overcome these challenges, the use of a bronchoscope with a reduced external diameter (ultrathin bronchoscope) could be beneficial. In particular, because the ultrathin bronchoscope [7] can be advanced close to the lesion, guidance of the biopsy instruments is easier. In addition, the ultrathin bronchoscope can be negotiated to the difficult-to-reach areas of the endobronchial tree,[8] thus, it could be useful for the diagnosis of small peripheral pulmonary lesions.[9,10] However, because the number of bronchial branching increases as the bronchoscope advances further into the periphery, the path to the lesion is difficult to identify within the limited examination time even if bronchial branching is directly visible. In addition, endobronchial examination by itself does not provide the direction to the peripheral lesion. Intuitive bronchial path selection based on CT data is inaccurate even at the third- to fourth-generation bronchus levels,[11] and therefore cannot be applied to the levels of bronchi reached and observed by the ultrathin bronchoscope. In recent years, CT fluoroscopy has allowed real-time confirmation of the positions of the bronchoscope, sampling instruments, and the lesion, and has been useful for the diagnosis of small

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peripheral lesions.[10,12,13] However, because the radiation exposure dose and the procedure time are significantly increased, path selection before the bronchoscopy is important.

Virtual bronchoscopic navigation (VBN) is a method in which bronchial path to the peripheral lesion is produced from virtual bronchoscopy (VB) images and used as a guide to navigate the bronchoscope. Because the bronchial branching pattern on VB images is similar to real bronchoscopic images, the bronchoscope can be advanced close to the target lesion according to the bronchial path to the lesion displayed on VB images. In addition, a system has been developed and applied that allows the automatic production of VB images of the bronchial path and their simultaneous display with real bronchoscopic images for navigation. VBN has been used in combination with CT-guided ultrathin bronchoscope, x-ray fluoroscopic bronchoscopy, and endobronchial ultrasonography with a guide sheath (EBUS-GS), and has been reported to reduce the examination time and increase the diagnostic yield. Its clinical application has also been reported. In this report, the author discusses VBN and the automatic VBN system, reviews the published literature, and describes its usefulness and limitations.

VIRTUAL BRONCHOSCOPY

Helical CT provides 3D serial volume data. VB is a method for a 3D fly-through display of the border between the bronchial lumen and the bronchial wall viewed from the bronchial lumen, as if it were observed using a bronchoscope.[14]

There are various 3D display methods. MPR (Multi Planner Reconstruction) can display any cross-sectional image. In addition to 2D planar axial slices, 3D observation of sagittal and coronal MPR images is useful in gaining an understanding of the lung structure including the airway.[15,16] However, branching structures along the bronchial path to the target are difficult to show in a single cross-sectional image. In addition, although cross-sectional images of the path can be displayed by curved multiplanar reconstruction (CMPR), the direct use of this data for the guidance of the bronchoscope is difficult. CT bronchoscopy is a method for the 3D display of the external appearance of the bronchial tree, but cannot be directly used for bronchoscopy. On the other hand, VB images reflect the actual anatomic findings[17] and provide useful data for the guidance of the bronchoscope, such as the bronchial branching pattern viewed from the bronchial lumen (ie, the size and shape of the entrance to the bronchi at the branching site, the branching angle, and bronchial arrangement after branching).

Compared with real bronchoscopy, VB is noninvasive and has no adverse effects except radiation exposure. VB allows the display of areas peripheral to stenotic areas, and also the display of extramural structures simultaneously with endobronchial images using the volume rendering method.[18] Therefore, VB has been used for the evaluation of airway stenosis,[19,20] tracheal/bronchial injury, endobronchial malignancy,[21] airway lesions in children with attention to exposure dose,[22] foreign bodies in the airway,[23] and postoperative bronchial complications.[24] VB is also used for the education of bronchoscopists,[25,26] transbronchial needle aspiration (TBNA),[27] stent placement,[28] and the planning of interventions,[14,29] such as brachytherapy and laser photoresection.

However, conventional CT and software have demonstrated limitations in the visualization of the bronchi peripheral to the segmental bronchi, showing reduced consistency with actual anatomic findings.[19,30] Therefore, the clinical use of VB is limited to the central bronchi.

In recent years, multidetector CT has allowed physicians to obtain finer isotropic voxel data, reduce respiratory and cardiac motion artifacts, and facilitate more detailed and accurate three-dimensional CT reconstruction. In addition, because of recent advances in computers, real-time display of arbitrary endobronchial images has become possible.[31,32]

VIRTUAL BRONCHOSCOPY NAVIGATION

Virtual bronchoscopy navigation is a VB method clinically applicable to arrive at the peripheral lesions. Virtual images of the bronchial path to the lesion are produced and used for navigation at the time of advancing the bronchoscope.[33] In the case that the author first reported, virtual images up to the tenth-generation bronchus comprising the bronchial pathway to the target were displayed simultaneously with real images, and an ultrathin bronchoscope (external diameter, 2.8 mm) could be advanced along the path to the target. Since this report, various studies on the usefulness of VBN have been published. Note that in articles published using Japanese nomenclature, including this article, all subsegmental bronchi, even those after repeated branchings as in the lower lobe, are regarded as third-generation bronchi and the number of further peripheral branchings is added to calculate the bronchial generation.[34,35] Therefore, when articles in Japan are compared with those in Western countries,