Virtual endobronchial ultrasound for transbronchial needle aspiration

Masaaki Sato, MD, PhD, Fengshi Chen, MD, PhD, Akihiro Aoyama, MD, PhD, Tetsu Yamada, MD, Masaki Ikeda, MD, Toru Bando, MD, PhD, and Hiroshi Date, MD, PhD

Objective: Endobronchial ultrasound-guided transbronchial needle aspiration could be performed better with computer-based preparation.

Methods: Three-dimensional virtual bronchoscopy was used to develop 2 modes of computer-based ''virtual endobronchial ultrasound.'' ''Virtual endobronchial ultrasound standard'' used conventional virtual bronchoscopy to determine the spot and angle for transbronchial needle aspiration, which was further evaluated by virtual bronchoscopy. ''Virtual endobronchial ultrasound advanced'' used multiple layers of 3-dimensional images of the target lesions and associated vascular structures in combination with virtual bronchoscopy. Target lesions and associated vascular structures (eg, pulmonary artery) were visualized through half-transparent bronchial walls.

Results: Both methods required 5 to 15 minutes of preparation per case. Virtual endobronchial ultrasound standard required only basic computer software for virtual bronchoscopy, whereas virtual endobronchial ultrasound advanced required an advanced computer application. Virtual endobronchial ultrasound advanced allowed for a more intuitive recognition of the target. Both methods were useful in evaluating the feasibility of transbronchial needle aspiration, especially when the target was out of regular mediastinal lymph nodes, or in targeting a lesion located at a high upper angle (eg, 4L lymph node). Because the puncture spot was predetermined, bronchoscopists did not have to search for the target using ultrasound at the time of actual endobronchial ultrasound-guided transbronchial needle aspiration; rather, ultrasound was used only for confirmation of the target location and visualization of transbronchial needle aspiration.

Conclusions: Both computer-based preparation methods of virtual endobronchial ultrasound were useful in predetermining the puncture spot of transbronchial needle aspiration, suggesting their potential complementary role to the conventional technique of endobronchial ultrasound-guided transbronchial needle aspiration. (J Thorac Cardiovasc Surg 2013;146:1204-12)

Endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA) is a minimally invasive method of mediastinal biopsy performed under direct, real-time endobronchial ultrasound guidance.[1-3] Beyond the lymph node stations reachable by mediastinoscopy (numbers 2, 4, and 7), EBUS-TBNA can obtain biopsies from hilar lymph nodes (numbers 10, 11, and 12). Moreover, EBUS-TBNA is useful for diagnosing mediastinal lesions other than those in conventional lymph nodes, such as mediastinal tumors,[4] and obtaining biopsies of centrally located intrapulmonary mass lesions that cannot be diagnosed by conventional flexible bronchoscopy.[5,6]

However, EBUS-TBNA is more technically demanding than standard fiber-optic bronchoscopy; there is a learning curve of 5 to 10 procedures for an experienced bronchoscopist to obtain clear ultrasound images.[7] Furthermore, EBUS-TBNA can be even more challenging for experienced EBUS bronchoscopists depending on the location of the target lesions.

Virtual bronchoscopy uses 3-dimensional (3D) reconstruction of 2-dimensional helical computed tomographic images for noninvasive evaluation of the tracheobronchial tree.[8] We recently introduced 3D virtual bronchoscopy as an aid to EBUS-TBNA and named the strategy ''virtual EBUS.'' In the present report, we describe simple techniques of 3D virtual bronchoscopy that enables predetermination of the puncture spot of TBNA. We describe 2 separate strategies, one using simple conventional 3D virtual bronchoscopy (''virtual EBUS standard'') and the other using more complex, multilayer virtual bronchoscopy to visualize target lesions and associated vasculature through half-transparent bronchial walls (''virtual EBUS advanced'').

MATERIALS AND METHODS

Virtual Endobronchial Ultrasound Standard

An Aquarius Thin Client Viewer (TeraRecon, Inc, Tokyo, Japan) was used to construct 3D virtual bronchoscopy images and simulate EBUS-TBNA on a computer. Step-by-step instructions are shown in Figure 1, *A*. First, following the manufacturer's instructions, 3D virtual

From the Department of Thoracic Surgery, Kyoto University Hospital, Kyoto, Japan.
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Address for reprints: Masaaki Sato, MD, PhD, Department of Thoracic Surgery, Kyoto University Hospital, 54 Kawahara-chyo, Shyogoin, Sakyo-ku, Kyoto 606-8507, Japan (E-mail: satomasa@kuhp.kyoto-u.ac.jp).
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Abbreviations and Acronyms

CT	= computed tomography
EBUS-TBNA	= endobronchial ultrasound-guided transbronchial needle aspiration
PET	= positron emission tomography
3D	= 3-dimensional

bronchoscopy images were constructed from thin-slice computed tomography (CT) images (Figure 2, *A-C*). Second, while paying attention to the 3D virtual bronchoscopic images and associated CT views (especially the axial view), the virtual bronchoscope was moved forward and backward in the tracheobronchial lumen. Throughout the process, the target lesion was localized on 3D images, and the angle at which the TBNA needle should penetrate the tracheal or bronchial wall was determined (Figure 2, *D*). Third, after determining the location and angle for puncture, only 3D virtual bronchoscopic images were used. Starting from the cephalic trachea and moving to the carina, 3D virtual bronchoscopy was performed as actual fiber-optic flexible bronchoscopy would be performed. While approaching the predetermined target, the operator ''imagined'' that he or she was a needle at the tip of the EBUS scope penetrating the tracheobronchial wall into the target (Figure 2, *D, far right*). When the virtual bronchoscope penetrated the tracheobronchial wall and the operator considered the target to be ''punctured,'' the CT views were opened and the puncture was evaluated by a pyramid-shaped director. If the target had not been appropriately punctured or the angle had not been appropriate, the second step was repeated to obtain a better puncture point.

Once the localization and puncture angle were determined, the 3D image was recorded with inclusion of notes that would guide an EBUS operator at the time of actual EBUS. We copied a series of 3D virtual bronchoscopy images and pasted them onto a presentation file (PowerPoint; Microsoft Japan, Tokyo, Japan) with an arrow indicating the spot and angle at which to puncture the target as a reference at the time of EBUS. It is also important to leave a concrete verbal description indicating the spot and angle to puncture (eg, 1 ring cephalad to the carina, 10- to 11-o'clock angle relative to the carina).

Virtual Endobronchial Ultrasound Advanced

An Aquarius iNtuition Client Viewer (TeraRecon, Inc, Tokyo, Japan) was used to build 3D images from thin-slice CT scans. Step-by-step instructions are shown in Figure 1, *B*. Virtual EBUS advanced is characterized by color-marking of target lesions and other associated structures (eg, blood vessels), and their visualization is performed by making tracheobronchial walls half-transparent. After loading CT images, masks (or layers) were created by tracking the outline of target lesion(s) and associated structures using the ''free drawing'' tool among the mask tools (Figure 3, *A-C*). The object was extracted by the ''extraction'' tool and then colored appropriately (eg, target lesion, green; pulmonary artery, red; and azygous vein and superior vena cava, blue) (Figure 3, *A-C, insets*). Each mask and the 3D bronchoscopy image were overlaid. Transparency of the 3D bronchoscopy image was manually adjusted, and pictures or movies were then recorded following the manufacturer's instructions (Figure 3, *D*).

Endobronchial Ultrasound-Transbronchial Needle Aspiration Procedure

The convex probe of the endobronchial ultrasound was used to perform EBUS-TBNA (BF-UC160F-OL8; Olympus, Tokyo, Japan). The

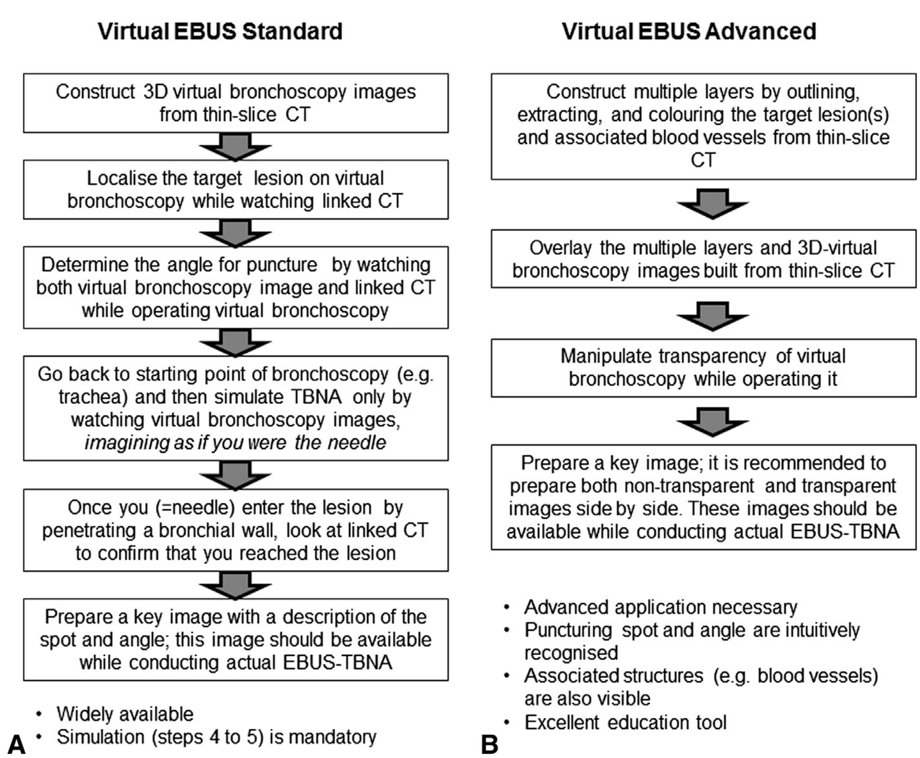

FIGURE 1. Step-by-step instructions and characteristics of virtual EBUS using virtual bronchoscopy. A, Virtual EBUS standard uses conventional 3D virtual bronchoscopy constructed from thin-slice CT. B, Virtual EBUS advanced uses an advanced application that allows for displaying multilayers, including extracted 3D images of target lesions, associated vascular structures, and 3D virtual bronchoscopy. *3D,* 3-Dimensional; *CT,* computed tomography; *EBUS-TBNA,* endobronchial ultrasound-guided transbronchial needle aspiration.