An Overview of Endobronchial Ultrasonography

Introduction (A History of Endobronchial Ultrasonography)

Endobronchial ultrasonography (EBUS) is a diagnostic modality whereby a miniature ultrasonic probe is introduced into the bronchial (tracheal) lumen, providing tomographic images of the peribronchial (peri-tracheal) tissue. Endoscopic ultrasonography (EUS) is already an indispensable technique for examining the gastrointestinal tract, particularly the stomach and large intestine. Applications of EUS include assessment of the depth of tumor invasion, detection of lymph node metastases, tumor staging, and fine needle aspiration (FNA) under EUS guidance.

The first reported clinical use of a narrow gauge ultrasonic probe was for intravascular ultrasonography by Pandian et al. [1] in 1988. The history of EBUS began with the report by Hürter et al. [2] of endobronchial ultrasonography of the lung and mediastinum in 1990. Since then, development and research has been carried out mainly by Becker (Germany) and ourselves (Japan).

EBUS probes are typically of the 20 MHz radial type. Tissue penetration of the ultrasound waves is therefore of the order of 2–3 cm; in other words, EBUS provides a tissue cross-section image with a radius of 2–3 cm centered on the trachea or bronchus.

Some important EBUS reports include the following:

1 Hürter 1990. Endobronchial sonography in the diagnosis of pulmonary and mediastinal tumors [in German] [2].


4 Goldberg 1994: US-assisted bronchoscopy with use of miniature transducer-containing catheters (delineation of central and peripheral pulmonary lesions) [5].

5 Becker 1995: Endobronchial ultrasonography – a new perspective in bronchology? (tracheobronchial wall 7-layer structure) [6].

6 Kurimoto 1999: Assessment of usefulness of endobronchial ultrasonography in determination of depth of tracheobronchial tumor invasion (tracheobronchial wall 5-layer structure) [7]. Based on these studies, the present applications of EBUS are:

a Determination of the depth of tumor invasion of the tracheal/bronchial wall (allocation of patients to localized endobronchial treatments such as photodynamic therapy (PDT).

b Identification of the location of a peripheral lung lesion during bronchoscopic examination (more accurate than fluoroscopy in determining contact between lesion and bronchus, thereby reducing abrasions, the time to determine biopsy sites and duration of fluoroscopy).

c Qualitative diagnosis of peripheral lung lesions and differentiation between benign and malignant lesions.

d Determination of position and shape of peribronchial structures, particularly lymph nodes (at the time of transbronchial needle aspiration).

e Determination of spatial relationship between bronchus and lesion in the short axial image of the bronchus (if the bronchus is situated near the center of the lesion, the lesion may have arisen from the bronchus).
Problems arising from the application of EBUS until now, and the results of studies, include the following:
1 Standardization of how the layers in the tracheobronchial wall structure are interpreted (how many layers do you see?).
2 Changes in the layer structure of the tracheobronchial wall with the use of higher frequencies, e.g. 30 MHz.
3 Evaluation of the accuracy of qualitative diagnosis, and differentiation between benign and malignant lesions, from EBUS images of peripheral lung lesions.
4 Evaluation of peribronchial lymph node metastases.
5 Comparison of the diagnostic accuracy of EBUS-guided FNA and unguided FNA cytology and histology.
6 A worldwide standard nomenclature for this technique.
EBUS allows us to examine the state of the bronchial wall and extramural tissue that we are unable to visualize with bronchoscopy alone. This book will present an overview of EBUS with reference to actual clinical cases.

Principles of Ultrasonography

What is A Sound Wave?

Definition of Ultrasound

In general, ultrasound refers to sound wavelengths greater than 20 MHz that cannot be heard by the human ear. There are considerable variations in the range of frequencies audible to humans, however, so we often define sounds in terms of their purpose. In this case, ultrasound is “sound not intended for humans to hear”.

Frequency and Wavelength

The frequency of a sound tells us whether it is high or low in pitch. The unit of frequency is hertz (Hz), defined as the number of oscillations per second. For example, a sound with a frequency of 20 MHz has $20 \times 10^6$ oscillations per second. Medical ultrasound equipment produces sounds with a frequency between 2 MHz and 50 MHz. The wavelength is the length of a soundwave, and varies inversely with the frequency, so the higher the frequency the shorter the wavelength (Figure 1.1).

Speed of Sound

Sound travels through a variety of materials such as air and water (hereafter media), and the speed at which it travels through each medium is the speed of sound for that medium. The speed of sound through the human body is generally considered to be 1530 m/s, although the actual speed of passage varies for different organs and tissues.

Production of Ultrasound Images

Transmitting and Receiving Ultrasound Waves (Figure 1.2)

Ultrasonic probes used in medical ultrasonography use a sensor that transforms electrical signals into ultrasound, and ultrasound into electrical signals. When an electric signal is applied to the electrode of the ultrasonic transducer (also oscillator/transformer), ultrasound waves are transmitted from the surface of the device, and when ultrasound waves are received by the device surface, an electrical signal is generated.

Propagation and Attenuation of Ultrasound Waves

The ultrasound waves produced by the ultrasonic transducer travel through a medium; this is called propagation. As the soundwave is propagated, the energy of its oscillations is absorbed and scattered, and becomes steadily weaker. This phenomenon is called attenuation. In general, the higher the frequency, the greater is the attenuation rate. Medical ultrasonography equipment uses high frequencies that do not propagate well through the air due to the high attenuation ratio. A medium such as water is therefore needed between the ultrasonic transducer and the object of study to allow efficient propagation of ultrasound waves.
CHAPTER 1 An Overview of Endobronchial Ultrasonography

Reflection and Penetration
As with light, a proportion of ultrasound waves are reflected at the boundary between different media, and a proportion penetrate the boundary. The ultrasonic processor uses these reflections to construct images.

The ultrasonic transducer emits pulses of ultrasound, and receives the ultrasound pulses reflected from the boundaries between media (Figure 1.3). The ultrasonic processor calculates the positions (distance from the probe) of boundaries between media based on the time between transmitting and receiving ultrasound pulses, and converts the strength of the returning pulses into the brightness of the image.

Following the above steps alone gives information about a body along a single line, so we obtain a two-dimensional image by moving the ultrasonic transducer (mechanical scanning) or using a linear array of multiple ultrasonic transducers that sequentially emit and receive ultrasound pulses (electronic scanning). This method of ultrasound imaging is called B-mode (B is for brightness).

Resolution
Axial Resolution
An ultrasound pulse wave has a definite length, so a boundary between media has a definite width on an ultrasound image. If we reduce the distance between the two boundaries of a medium, the pulse waves from the two boundaries will overlap, making it difficult to distinguish the two boundaries on the ultrasound image. The ability to distinguish between objects on an ultrasound image is called the resolution, and the resolution in the direction traveled by the ultrasound pulse is the axial resolution. In general, the higher the frequency the shorter the ultrasound pulse, so distance resolution improves with higher frequencies (Figure 1.4).
Lateral Resolution
Resolution in the direction perpendicular to the direction traveled by the ultrasound pulse, in other words in the direction the probe moves or in the direction of the array of transducers, is called the lateral resolution. The ultrasound pulse wave emitted by the transducer gradually spreads out as it propagates through a medium. The degree of spread depends on the transducer size (aperture area) and the frequency. As the transducer size and/or frequency increases, the degree of spreading decreases (Figure 1.5). Lateral resolution improves with decreased spread (Figure 1.6).
Depth Penetration
Ultrasound waves are attenuated as they propagate through a medium, so they can only reach a certain distance. Ultrasound images can therefore only be attained for a certain distance from the ultrasonic probe. This distance is called the depth penetration (or penetration). The depth penetration also depends on the frequency and the transducer size (aperture area). The attenuation rate of an ultrasound wave increases as its frequency increases, so depth penetration improves as the frequency decreases (Figure 1.7). As the aperture area of the ultrasonic transducer increases, it can emit a stronger pulse, and it can also convert weaker received pulses into electrical signals. Depth penetration therefore increases as the transducer size increases.

Image Quality Adjustment
Even when using an ultrasonic probe appropriate to the task, its abilities cannot be fully harnessed unless appropriate image quality adjustment is performed. The fundamentals of image quality adjustment are gain, contrast and sensitivity time control (STC).

Gain
Gain, also called brightness, is the mechanism for adjusting the overall brightness of the ultrasound image. Adjustment of the gain increases or decreases the entire ultrasound signal (the signal from the ultrasonic transducer converted for display on the monitor) evenly. Changes in the gain make the entire image brighter or darker, but do not alter the differences in brightness between light and dark sections of the image (Figure 1.8).

Contrast
Contrast is the mechanism for adjusting the difference in brightness between light and dark sections of the image. Adjustment of the contrast makes the greatest changes in the sections of the image with the strongest
ultrasound signal, in other words changing the contrast mainly alters the brightness of the lighter sections of the image, and the darker sections are changed but little. Increasing the contrast of an ultrasound image yields an image with enhanced differences between light and dark areas, whereas decreasing the contrast yields an image with minimal differences between light and dark areas (Figure 1.9).

**Sensitivity Time Control**

Sensitivity time control (STC) also known as time gain compensation (TGC), is the mechanism for adjusting the gain according to the distance (depth) from the ultrasonic probe. As shown in Figure 1.7, attenuation of the ultrasound wave increases with the distance from the probe, so ultrasound signals from distant (deep) regions are weaker than those from near (shallow) regions. In order to correct this and make the overall image as even as possible, the ultrasonic processor amplifies the ultrasound signal according to the current distance from the probe (the time for the ultrasound pulse to return to the transducer) (Figure 1.10). By altering the degree of amplification, adjustment of STC can make the ultrasound image lighter or darker according to the distance from the probe (Figure 1.11).

**Procedure for Image Quality Adjustment**

Image quality adjustment should be conducted in accordance with the properties of the ultrasonic processor, monitor and printer. Adjustment of gain (brightness) and contrast are performed in the following manner:

1. Switch on the system, and bring up an image on the monitor (Figure 1.12).
2. Adjust the brightness and contrast controls of the monitor so that the gray scale bar in the ultrasound image is displayed with smoothly varying gradations (Figure 1.13).
3 Adjust the brightness and contrast controls of the printer so that the gray scale bar in the printed image corresponds closely to the monitor image.

4 Adjust the gain, contrast and STC of the ultrasonic processor according to the study subject and purpose of the study. When the EU-M30 system is used with a 20 MHz ultrasonic probe, images with appropriate gradations can be obtained by setting the gain to between 10 and 13, the contrast to between 2 and 5, and the STC to all zero (center position).

### Equipment

**Endoscopic Ultrasonic Probe**

In this section, we will introduce the equipment used by the author, manufactured by Olympus Corporation.

The frequencies and outer diameters of the endoscopic ultrasonic probes we use are shown in Table 1.1. Since the resolution and depth penetration of an ultrasonic probe are dependent on the frequency and size of the transducer (as the outer diameter of the probe increases, the size of the ultrasonic transducer also increases), the probe needs to be selected to suit the aim of the procedure.

Ultrasound examinations can be performed using either the balloon (the probe contacts the object of study through a balloon filled with medium)

<table>
<thead>
<tr>
<th>Model name</th>
<th>Maximum outer diameter</th>
<th>Frequency</th>
<th>Compatible biopsy channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>UM-2R</td>
<td>2.5 mm</td>
<td>12 MHz</td>
<td>2.8 mm or more</td>
</tr>
<tr>
<td>UM-3R</td>
<td>2.5 mm</td>
<td>20 MHz</td>
<td>2.8 mm or more</td>
</tr>
<tr>
<td>UM-4R</td>
<td>2.4 mm (2.0 mm at proximal side)</td>
<td>20 MHz</td>
<td>2.6 mm or more</td>
</tr>
<tr>
<td>UM-S20-20R</td>
<td>1.7 mm (2.0 mm at proximal side) 2.55 mm (incl. guide sheath SG-201C)</td>
<td>20 MHz</td>
<td>2.2 mm or more 2.6 mm or more</td>
</tr>
<tr>
<td>UM-S30-20R</td>
<td>1.7 mm (2.0 mm at proximal side) 2.55 mm (incl. guide sheath SG-201C)</td>
<td>30 MHz</td>
<td>2.2 mm or more 2.6 mm or more</td>
</tr>
<tr>
<td>UM-S30-25R</td>
<td>2.5 mm</td>
<td>30 MHz</td>
<td>2.8 mm or more</td>
</tr>
<tr>
<td>UM-BS20-26R</td>
<td>2.6 mm (incl. balloon sheath MAJ-643R)</td>
<td>20 MHz</td>
<td>2.8 mm or more</td>
</tr>
<tr>
<td>UM-S20-17S</td>
<td>1.4 mm (1.7 mm at proximal side) 1.95 mm (incl. guide sheath SG-200C)</td>
<td>20 MHz</td>
<td>2.0 mm or more 2.0 mm or more</td>
</tr>
</tbody>
</table>
or direct contact method (the probe makes direct contact with the object of study). The method is usually selected according to whether the object of study is centrally or peripherally situated, and probe selection is also made according to the region being examined.

When the balloon method is used, the UM-BS20-26R ultrasonic probe (which can be inserted in a bronchoscope instrument channel with a diameter of at least 2.8 mm) is generally used (Figures 1.14, 1.15). Other probes can also be used in the balloon method in combination with the balloon sheath MH-246R (Figure 1.16, outer diameter 3.6 mm). This will require a special bronchoscope such as the BF-ST49, with an instrument channel with a diameter of at least 3.7 mm, or a rigid bronchoscope with an instrument channel of 11.5 Fr or more.

The direct contact method does not require a balloon, so the probe is passed directly down the bronchoscope instrument channel.

**Bronchoscope**

Having selected the ultrasonic probe in accordance with the aim of the investigation and the region being examined, it is then necessary to select a bronchoscope suitable for use with that probe. In particular when the balloon method is selected, care must be taken to prepare a bronchoscope with an instrument channel diameter of at least 2.8 mm. Table 1.2 shows the endoscopes compatible with the various probes.
### Table 1.2 Compatibility between bronchoscopes and ultrasound probes

<table>
<thead>
<tr>
<th>Bronchoscopes</th>
<th>Guide sheath method</th>
<th>Direct contact method</th>
<th>Balloon method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UM-S20-17S</td>
<td>UM-S20-20R/UM-S30-20R</td>
<td>UM-4R</td>
</tr>
<tr>
<td>BF-200/240*1</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>BF-P200/P240*1</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>BF-6C240*1</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BF-160/MP160F*2</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>BF-P150/P160/P180*2</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>BF-Q180*2</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BF-Q180-AC*2</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BF-260/6C260</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BF-MP60</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BF-P260F</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>(2.0 mm CH)</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BF-30*1</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>BF-40</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BF-P30/P40*1</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BF-P60</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BF-20D/P20D*2</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BF-PE/PE2*2</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>(2.2 mm CH)</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BF-1T200/1T240*1</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>(2.6 mm CH)</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BF-1T30/1T40*1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BF-1T240R*1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BF-1T150/1T160*2</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BF-1T260</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BF-LT30</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BF-1T20D*2</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BF-TE/TE2*2</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(2.8 mm CH)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BF-1T60/1T180*2</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(3.0 mm CH)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BF-XT20/XT30*1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BF-XT40</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BF-XT160*2</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(3.2 mm CH)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BF-ST40*1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(3.7 mm CH)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*1: Discontinued model.
*2: Not available in Japan.
Select a bronchoscope which can be used with an ultrasonic probe. When the balloon method is selected, it is necessary to use an endoscope that has an instrument channel diameter of 2.8 mm or more.

**Ultrasonic Processor and Probe Driving Unit**

Ultrasound images are obtained by attaching the endoscopic ultrasound probe to the Endoscopic Ultrasound Center EU-M2000 (Figure 1.17a) via the Probe Driving Unit MH-240 (Figure 1.17b).

The EU-M30 videoconverter system is fully compatible with both videoscopes and fiberscopes, and its subscreen function allows simultaneous display of both ultrasound and endoscopic images on the one monitor, or switch between images (Figure 1.18). The EU-M30 ultrasonic processor is compatible with frequencies from 7.5 to 30 MHz, can be used for distance and area calculations, and is compatible with gastrointestinal endoscopic ultrasound (EUS) and a variety of endoscopic ultrasonic probes. It is highly compact, and fits on the standard endoscopic equipment trolley.

The EU-M30S (Figure 1.19) ultrasonic processor is designed for use with miniature probes. It is equipped with a probe drive unit as standard, and the main unit is compact and highly portable. This probe-dedicated system makes it easy to obtain high quality ultrasound images, and includes full image quality adjustment functionality.

**Preparations**

**Required Equipment**

- Ultrasonic probe (sterilized).
- Balloon sheath.
- Balloon sheath connector (for attachment of the balloon sheath to the probe).
- 3-way stopcock with extension tube.
- Sterile water or physiological saline, 20 mL.
- 20 mL syringe.

**Assembling the Balloon Probe**

**Using the Endoscopic Ultrasound Probe UM-BS20-26R**

The advantages of this probe are that it can be used with flexible bronchoscopes with a standard instrument channel with a diameter of at least 2.8 mm (BF-IT20, IT30, IT40, IT240R), and balloon deflation has become simpler.
Assemble the balloon probe in accordance with the instructions in the manual provided.

a Pass the balloon sheath connector from the probe tip down, and fix it to the balloon sheath connector attachment on the probe.
b Insert the balloon sheath from the probe tip, and press the balloon sheath clasp into the balloon sheath connector.
c The optimum position for the ultrasonic transducer is not in the center of the balloon, but rather the transducer should just protrude from the base of the balloon (Figure 1.20). This allows the transducer to rotate within the maximally expanded portion of the balloon when it has been inflated.
d Draw up 15 mL of sterile water (or physiological saline) into the syringe, fill the 3-way stopcock extension tube with water, and attach the extension tube to the balloon sheath connector inlet.
e Pull back on the syringe to create negative pressure, drawing out as much air as possible from between the balloon sheath and probe. After performing this step three times, slowly release the negative pressure and then slowly fill inject sterile water into the balloon.
f Continue to push the syringe plunger with the balloon tip pointing upwards, filling the balloon with water. Although a small bubble of air will enter the balloon, the tip of the balloon is separate, with a hole in it. Pulling the balloon in the direction of the tip, express the air and water in the tip.
g After all air in the balloon has been eliminated, fix the probe by hand through the balloon, and push the O-ring on the balloon tip into the groove in the probe tip, by hand or using a balloon applicator (Figure 1.21). Once the balloon has been filled with water, and checked for leaks and air bubbles, preparation is complete (Figure 1.22).

Connection of the Probe to the Driving Unit
Insert the connection pin of the ultrasonic probe into the connector on the driving unit, pointing the pin at the 12 o’clock position.

Connecting the Power and Data Entry
Only turn on the power to the Ultrasound Center after the probe has been connected. The ultrasonic probe will be damaged if it is connected when the power is on. After the power has been connected, switch the monitor to the ultrasound input, and enter the patient’s identity number, age and name.
**Checking the Image**

Unfreeze and rotate the ultrasonic probe. If it is working properly, multiple echoes with five to seven layers will be seen centered on the probe. If multiple echoes are not seen, the probe may be disconnected or there may be air bubbles in the medium in contact with the probe.

**Inverting the Image**

Next press the “Image Direction” switch to change the monitor image from normal to inverse. This inverts the ultrasound image so that left and right are the same as the endoscopic image, to an image seen from the rostral direction. In gastrointestinal EUS, the normal ultrasound image is seen from the caudal direction, for easy comparison with computer tomography (CT) scans, but in EBUS it is desirable for the directions in the ultrasound image to coincide with the image from the bronchoscope, for the purposes of FNA from the tracheobronchial lumen. The normal mode is only used in special situations, such as for comparison with CT images.

**Operation**

**Anesthesia**

In principle, anesthesia for EBUS is the same as for regular bronchoscopic examinations. It should be kept in mind, however, that until the operator has become more experienced, procedures will tend to be somewhat longer in duration. When EBUS is performed in conjunction with another procedure, such as laser-induced fluorescence endoscopy (LIFE), then intravenous anesthesia may be used, allowing spontaneous respiration. An important consideration for the anesthetist is to confirm, under direct observation using the laryngoscope, that local anesthetic spray is applied directly to the pharynx and larynx, in particular to the vocal chords. After bronchoscopic examination of the trachea and bronchi, local anesthetic is further applied to the bronchus (bronchi) into which the balloon probe will be introduced.

**Inserting the Probe**

Apply xylocaine jelly liberally to the distal end of the balloon probe, and slowly insert it into the instrument channel of the bronchoscope. During the insertion process, hold the probe at a point 2 or 3 cm away from the instrument port with each hand in turn. It is important to be aware that there are two places with greater resistance within the instrument channel, between the instrument port and the distal end of the bronchoscope. The first site is 4–5 cm from the instrument port, where the suction and instrument channels join, and the second is 2–3 cm from the bronchoscope tip, where the instrument bends. When resistance is high at either site and the probe is difficult to pass, then the probe should be removed and jelly reapplied, and if that fails, remove the bronchoscope from the patient and reinsert the probe.

**Operating the Probe**

Advance the probe to a point slightly distal to the site of interest. Inject 1–3 mL of sterile water (physiological saline may also be used with the UM-BS20-26R), inflating the balloon while scanning so that it contacts the bronchial wall circumferentially. The optimum volume of water is that which just achieves circumferential contact with the bronchial wall. Over-inflation can cause compression of bronchial wall structures or bursting of the balloon.

Then, while scanning and capturing images (always make a videorecording), retract the probe from deep (distal) to superficial (proximal). The important point to remember about scanning is to retract the probe very slowly. If necessary, ask the patient to hold their breath while scanning. Advancing the probe from superficial (proximal) to deep (distal) can cause damage to the probe, and should be avoided.

**Tips for Achieving Optimum Ultrasound Images**

To obtain clear, easily understandable images:

- **a** Rotate the ultrasound image so that it corresponds to the endoscopic images.
- **b** To assess the depth of tumor invasion, the ultrasound pulse must penetrate the tracheal/bronchial wall perpendicularly.

**Rotate the Ultrasound Image So that It Corresponds to the Endoscopic Images**

- **i** At a bifurcation (e.g. the opening of the right upper lobe bronchus), we can line up the direction so that the balloon is not in contact with the bronchial lumen.
on the endoscopic image, with no echo on the EBUS image.

ii For example (Figure 1.23), in the left ultrasound image below, the direction has no echo, because the balloon is not in contact with the bronchial lumen, and direction is from 4 to 6 o’clock. In the right endoscopic image, the balloon is not in contact with the bronchial lumen and direction is from 2 to 4 o’clock. To match up the images, we need to rotate the EBUS image anticlockwise 45°.

iii Rotate the EBUS image according to the relative positions of the bronchial tree and the esophagus and great vessel.

When scanning from the lower part of the trachea to the left main bronchus, the esophagus is located at the 6 o’clock direction (Figure 1.24 left). The right pulmonary artery runs anteriorly to the right main bronchus and right middle lobe bronchus, from 10 o’clock to 2 o’clock (Figure 1.24 right). Identify the position of these structures, and rotate the EBUS image accordingly.

To Assess the Depth of Tumor Invasion, Obtain Images with the Ultrasound Pulse Penetrating the Tracheal/Bronchial Wall Perpendicularly

If the first layer (marginal echo, reflected at the boundary between tissues) is highly echoic, the image can be said to be derived from an ultrasound pulse penetrating the tracheal/bronchial wall nearly perpendicularly (Figure 1.25).

Figure 1.23 Tips for achieving optimum ultrasound images. Rotation of the ultrasound image so that it corresponds to the endoscopic images.

Figure 1.24 Tips for achieving optimum ultrasound images. Rotation of the EBUS image according to the relative positions of the bronchial tree and the esophagus and great vessels.
Equipment of EBUS Guided Transbronchial Needle Aspiration (EBUS-TBNA)

The curved array transducer is combined at the tip of the bronchoscope for EBUS-TBNA (Figure 1.26, BF-UC160F, Olympus). This convex bronchoscope consists of an oblique forward viewer with a convex transducer mounted in front of the lens. The convex transducer is 7.5 MHz and covered by a balloon. The bronchoscope has a working channel with a diameter of 2.0 mm; we can insert the disposable biopsy instrument with a 22 G needle (Figure 1.27, NA-201SX-4022, Olympus) through the working channel (Figure 1.28).

After the convex probe is covered by the balloon, saline is injected into the balloon, filling its inner space. This bronchoscope is connected to the ultrasound unit (EU-C60) and the power switch turned on (Figure 1.29).

The scope shows us the target lesion for TBNA beyond the bronchial wall. The transducer provides longitudinal planes of peribronchial areas, and the ultrasonographic image shows us real-time movement of the TBNA needle.

As this convex bronchoscope has an oblique forward viewer, there is a little difficulty when inserting this scope through the vocal cord. Observing the 12 o’clock direction of the vocal cord, the tip of the scope is straight and it is easy to enter the trachea.


**Frequently Asked Questions**

1 Which generation of the bronchial tree needs the balloon to visualize the bronchial wall using EBUS?
A: From trachea to sub-sub or sub-sub-subsegmental bronchus, the balloon is necessary to obtain excellent images using EBUS.

2 Could the miniature probe reach the subpleural area?
A: Yes, the miniature probe of 1.4–2.5 mm in diameter expands to the subpleural area.

3 Which probe could penetrate the tissue deeper, a 20 MHz probe or 30 MHz probe?
A: 20 MHz probe could. As the frequency decreases, the depth penetration of the ultrasound pulse is increased.

4 What are tips for achieving satisfactory visualization of EBUS using the radial probe?
A: The probe should be located at the center of the lumen of the bronchial tree. As the ultrasonic waves penetrate the bronchial wall perpendicularly, excellent images are visualized.