Ultrathin Bronchoscopy: Indications and Technique

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Introduction and Definition of the Procedure

Standard flexible bronchoscopes may enter up to third- to fifth-generation bronchi and allow visualization of one to two further generations in adult patient airways, while the category of "ultrathin bronchoscope" can reach small peripheral airways up to 9th to 12th generation. Although no formal definition of "ultrathin bronchoscope" has been established, the term ultrathin has been widely used when referring to bronchoscopes with an outer diameter of 3 mm or less that are used for the exploration of peripheral airways in adult patients. In Fig. 3.1 you can compare the size of different bronchoscopes.

In this chapter we will review the technique and applications of the ultrathin bronchoscope.

History and Historical Perspective

The first ultrathin fiber-optic bronchoscope (FOB) was used through the working channel of a conventional bronchoscope. Developed by Tanaka et al. [1] in 1984, the model Olympus BF-1.8T was composed of fine optical glass fibers and had a tip diameter of 1.8 mm that could go up to 180 mm past the tip of a conventional fiber-optic bronchoscope. It had no working channel and could be bent passively only. Attachment to a special camera allowed for the first photographs of peripheral airways of 2 mm or less [2] and their

Fig. 3.1 Comparison of different bronchoscopes: 2.8, 4.9, and 6.0 mm external diameter

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first endoscopic classification [3]. By the same time, Prakash was using a regular pediatric fiber-optic bronchoscope (Olympus BF-3C4) with an external diameter of 3.5 mm to explore and sample with a cell brush the abnormalities present in more distal airways of adult patients [4]. In 1990 Tanaka et al. developed a second model of ultrathin with an outer diameter of 2.2 mm and distal tip that could be bent 120° upward and downward (Olympus BF-2.2T) [5]. Later in 1994 a new bronchoscope (Olympus BF-2.7T) was released by the same authors with a tip diameter of 2.7 mm and the novelty of incorporating a 0.8 mm working channel that allowed small airways sampling under direct vision with a cell brush (Olympus BC-0.7T) [6]. Since then, newer ultrathin fiber bronchoscopes and video bronchoscopes with working channels up to 1.2 mm have been developed as well as various types of brushes and biopsy forceps. Most recently, a new prototype of ultrathin hybrid bronchoscope with a working channel of 1.7 mm has been used that allows for radial probe EBUS performance [7]. A summary of the evolution of ultrathin bronchoscopes found in medical literature can be seen in Table 3.1. Pediatric bronchoscopes from other brands have also been used for exploring the peripheral airways of adult patients.

In essence, ultrathin bronchoscopes are thinner versions of the standard bronchoscopes. Although they can be used either in pediatric patients or in peripheral airways of adults, they are provided with longer insertion tubes than pediatric bronchoscopes.

Indications and Contraindications

Unlike standard flexible bronchoscopy which is divided into diagnostic and therapeutic categories, the use of ultrathin bronchoscopy is mainly diagnostic. As will be discussed later, its main limitation when sampling is the small working channel which limits both the suctioning capability and the use of instruments. In terms of contraindications, however, the same may apply.

Indications

The study of the peripheral pulmonary nodule is the main indication for ultrathin bronchoscopy.

Table 3.1 Evolution of ultrathin bronchoscopes

Image[a]	Year	Type	Working length (mm)	External diameter (mm)	Internal diameter (mm)	Tip angulation (up/down)	Additional imaging techniques	Instruments
nF	1984	Olympus BF-1.8T	950	1.8	–	–	–	–
F	1990	Olympus BF-2.2T	1150	2.2	–	120°/120°	–	–
F	1994	Olympus BF-2.7T	1200	2.7	0.8	120°/120°	–	Brush
F	1999	Olympus BF-XP40	600	2.8	1.2	180°/130°	–	
F	2004	Olympus BF-XP60	600	2.8	1.2	180°/130°	–	Brush and forceps
H	2004	Olympus BF-XP160F	600	2.8	1.2	180°/130°	–	
V	2014	Olympus BF-XP190	600	3.1	1.2	210°/130°	NBI	
H	2015	Olympus Y-0025[b]	600	3.0	1.7	180°/130°	–	Brush, forceps, and radial EBUS probe

[a]*F* fiber-optic bronchoscope, *H* hybrid bronchoscope, *V* video bronchoscope
[b]Prototype

In the review by Rivera et al. for the third edition of the ACCP guidelines, the overall sensitivity of flexible bronchoscopy for diagnosing central lesions was 88% while for peripheral lesions was 78% [8]. This is partly due to direct visualization of the lesion while sampling areas that the bronchoscope does not reach. The importance of the ultrathin bronchoscope relies therefore in the ability to reach and directly visualize the abnormalities of the peripheral airways, primarily peripheral pulmonary nodules, and its capability of sampling the periphery of the lung under direct visualization.

Although no specific guidelines regarding ultrathin bronchoscopy have been developed, its use is not limited to the study of the peripheral pulmonary nodule. Other uses may include the exploration of cavitated nodules if aspergilloma formation is suspected, the study of critical stenosis (Fig. 3.2) (where the use of the ultrathin may avoid the presence of asphyxia and even barotrauma due to its small diameter), or the study of postoperative scars. Asai et al. used an ultrathin bronchoscope to apply suction in a giant bulla, observing radiologic and functional improvement after 2 months [9]. Also, peripheral nodule marking with barium prior to surgery has been described [10].

Contraindications

The same contraindications as for standard bronchoscopy may apply. It has to be noted though that the ultrathin bronchoscope is a very fragile instrument, and therefore careful manipulation is imperative.

Description of the Equipment Needed

Ultrathin bronchoscopy may be performed in a bronchoscopy suit with the patient awake or in mild sedation or in the operating room under general anesthesia and endotracheal intubation.

The equipment needed includes:

- Trained staff: a skilled operator and two assistants (at least one of them should be a qualified nurse).
- Ultrathin bronchoscope and its accessories.
- Light source and video processor.

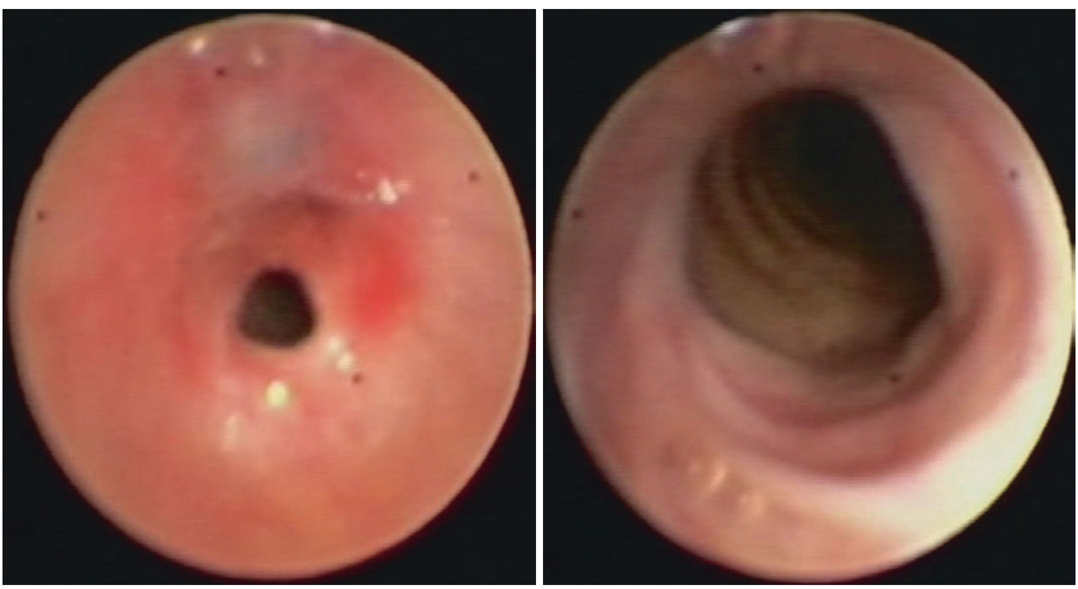

Fig. 3.2 Examination of critical stenosis with the ultrathin bronchoscope: view of the severe stenosis and distal trachea

- 50 mL syringes.
- Topical anesthesia: 2.5% lidocaine.
- Room temperature saline.
- Mini biopsy forceps and/or mini cytological brush (1 mm diameter).
- Specimen collection devices (bronchial washing receptacle, 95% alcohol and CytoLyt® solution).
- Cold saline should be ready to use in case of bleeding.
- Chest tube placement kit should be ready to use in case of pneumothorax.
- C-arm fluoroscopy or computed tomography (CT) should be available for guidance of the bronchoscope or sampling instruments, to verify their position and to confirm that no pneumothorax is present right after sampling.

Optional equipment:

- Virtual bronchoscopy or virtual bronchoscopic navigation for aiding in procedure planning and guiding.

In Fig. 3.3 you can see the operating room with the necessary equipment for ultrathin bronchoscopy with virtual bronchoscopic navigation performance in a patient under general anesthesia.

Procedure Description

The authors of the present text prefer performing ultrathin bronchoscopy under general anesthesia since it allows greater technical precision and better patient and operator comfort. Exploration of the peripheral airways can be a long procedure, and it is technically more challenging to manipulate the ultrathin through smaller bifurcations if the patient is not under a controlled respiration and in the absence of any movements or cough. Even more, having the patient under general anesthesia, it allows for a short controlled apnea application when sampling thus aiding in operator control of the instruments in the still peripheral lung. As in any case of general anesthesia, an anesthesiologist and qualified assistant as well as the necessary material for intravenous access, assisted ventilation, cardiorespiratory monitoring, and resuscitation equipment have to be available in the procedure room. While the diameter of the orotracheal tub is not relevant as ultrathin bronchoscope minimally compromises its lumen, its length needs sometimes to be shortened.

In those relatively tall patients with peripheral pulmonary lesions, the 600 mm working length of the ultrathin bronchoscope is not sufficient to

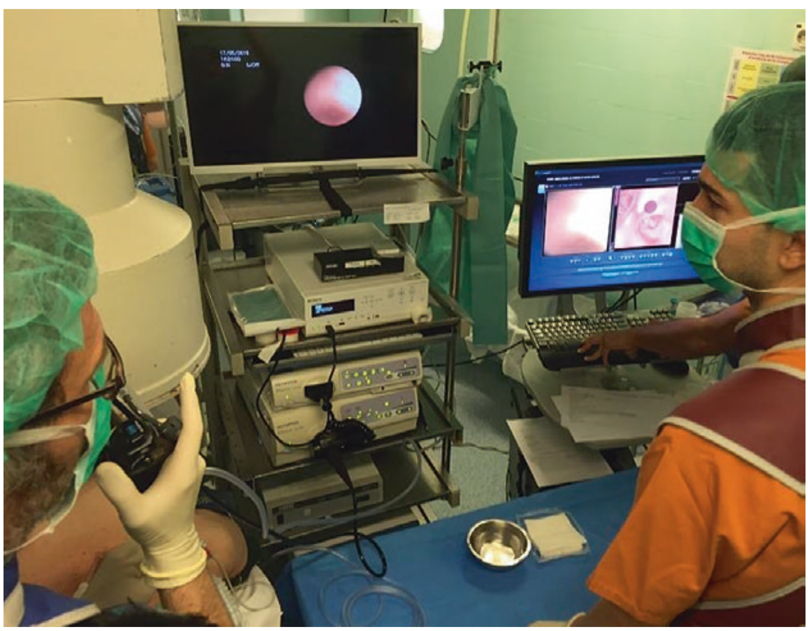

Fig. 3.3 Operating room: two bronchoscopists and one trained nurse performing ultrathin bronchoscopy with virtual bronchoscopic navigation (LungPoint®)

reach the target. In these cases, cutting some centimeters of the orotracheal tube proximal end might be helpful in order to further insert the ultrathin bronchoscope.

Planning a procedure in advance is a must when performing any technique, but this becomes especially relevant when concerning ultrathin bronchoscopy. A deep understanding of the anatomy of the airways is fundamental for the interpretation of the CT as well as for a meticulous three-dimensional reconstruction of the route through bronchial bifurcations to the peripheral pulmonary nodule. Although highly trained bronchoscopists have the ability to memorize the route, complementary technologies have been used since the beginning for assisting the bronchoscopist in this process of orientation throughout the bronchial tree. These assisting tools are mainly image based. Electromagnetic navigation is not feasible with the ultrathin scopes. Therefore, when talking about ultrathin bronchoscopy, it is understood that an image-based technique will complement the procedure either while planning or to verify the position of the ultrathin bronchoscope at any time during the procedure. Different image-based techniques can be used alone or in combination, and these include virtual bronchoscopy, virtual bronchoscopic navigation, fluoroscopy, and computed tomography. Radial EBUS has also been used in the diagnosis of the peripheral pulmonary nodules. A meta-analysis by Wang et al. [11] comparing diagnostic yields of different navigational techniques, including radial EBUS, ultrathin bronchoscopy, and the use of a guide sheath, showed a benefit for using guided bronchoscopy although no method proved being superior. Recently, a randomized, multicenter trial by Oki et al. [7] combined virtual bronchoscopic navigation, radial EBUS, and fluoroscopy with either a thin or a novel prototype of ultrathin bronchoscope. A total of 305 patients were randomized, and results showed a higher diagnostic yield with the ultrathin bronchoscope than with a guide sheath method (74% vs. 59%). It has to be noted that this novel prototype ultrathin bronchoscope had a 1.7 mm working channel that allowed the use of a radial probe EBUS and sampling with a 1.5 mm biopsy forceps.

In conclusion, to take most advantage of ultrathin bronchoscopy, it is important to consider combination with image-based techniques. The following paragraphs provide a detailed description of the procedure and complementary image-based techniques.

Planning the Procedure

One of the most relevant points to consider when planning the procedure on a CT image is the presence of a bronchus or artery afferent or within the nodule, the so-called bronchus sign [12] and artery sign [13]. When present, the sensitivity of ultrathin bronchoscopy is higher. A positive bronchus and artery sign are shown in Fig. 3.4.

Image-based techniques used for aiding in procedure planning include virtual bronchoscopy (VB) and virtual bronchoscopic navigation (VBN).

VB is based on multiplanar reconstruction and segmentation of the airways. Through dedicated software in the CT working station, it allows performing a virtual bronchoscopy through the segmented airways.

More recently, VBN software has been developed that allows the bronchoscopist to perform virtual bronchoscopy in the bronchoscopy suite. This provides the bronchoscopist with an on-site route map that can be followed while performing the procedure. However, VBN requires assis-

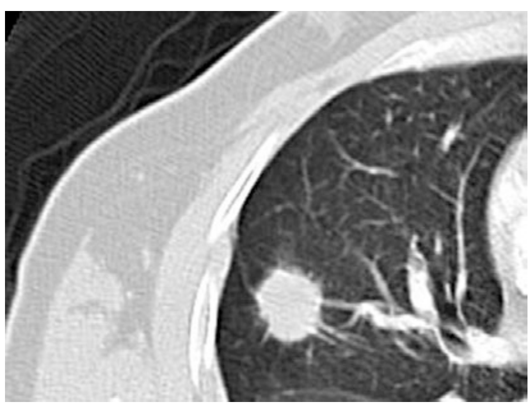

Fig. 3.4 Bronchus sign and artery sign

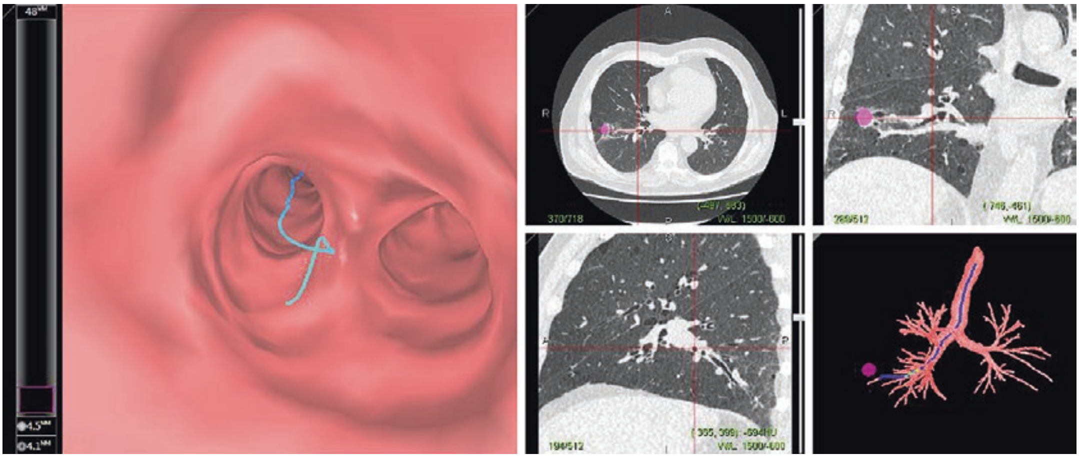

Fig. 3.5 A view of the LungPoint® planning system

tance by a trained bronchoscopist who performs the virtual bronchoscopy, while the operator follows the indications in each encountered bifurcation. A view of the LungPoint® planning system is shown in Fig. 3.5. VBN not only adds information to the path to be followed but also serves as an approximation of the position of the bronchoscope. However, VBN does not permit real-time tracking, and therefore a method for verifying the actual position of the bronchoscope is always necessary at this point.

Reaching the Target with the Ultrathin Bronchoscope

In our institution, the ultrathin bronchoscope is inserted through the endotracheal tube. This allows for a better path selection and maneuverability and better patient comfort as the procedure is usually long, and also it avoids damaging the scope. In Fig. 3.6 you can see black dots on the bronchoscopic image corresponding to broken fibers after the ultrathin fibrobronchoscope was accidentally bitten by a patient.

Due to the small diameter of the working channel, it becomes very difficult to carefully aspirate tracheobronchial secretions. If abundant secretions are present, performance of a bronchoscopy with a wider bronchoscope for secretion aspiration prior to examination with the ultrathin bronchoscope should be considered. In rare occasions, two instruments are used simultaneously (as seen in Fig. 3.7). When working at a subsegmental level besides the range of a bronchoscope, it is recommended that secretions are not aspirated and saline be continuously instilled instead. A 50 mL syringe is connected to the working channel and the assistant instills saline as requested. This allows for a better view of the airways since secretions are bypassed and lumen diameter widens. A view of ultrathin bronchoscopy in peripheral airways under saline infusion is shown in Fig. 3.8. When accessing the right upper lobe, it is recommended to leave the biopsy

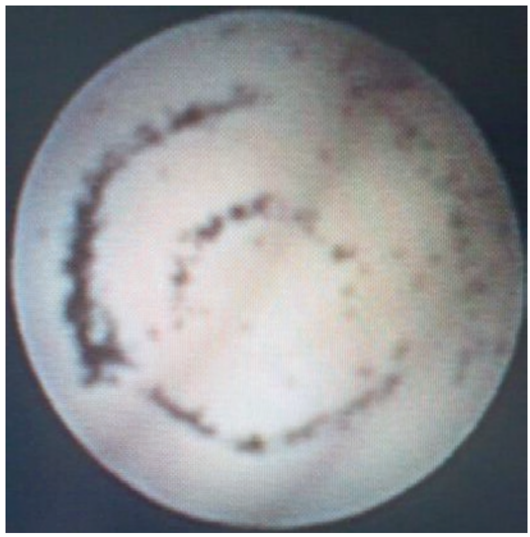

Fig. 3.6 *Black dots* corresponding to broken fibers after the ultrathin fibrobronchoscope was accidentally bitten by a patient

Fig. 3.7 Dual examination with an ultrathin bronchoscope and a standard bronchoscope to better suction secretions

forceps inside the working channel to gain stiffness and avoid bending backward 180°.

Fluoroscopy can be used to approximate visible lesions. It is not a guidance tool, but it can serve as a trial-and-error tracking tool since it gives information about target approximation accuracy.

VBN can also be used for aiding in target achievement. As previously noted, this method does not allow for real-time tracking of the ultrathin bronchoscope, but it can assist in pathway choice and faster nodule achievement. When using VBN systems, a trained bronchoscopist is needed to perform the virtual bronchoscopy through the previously selected path.

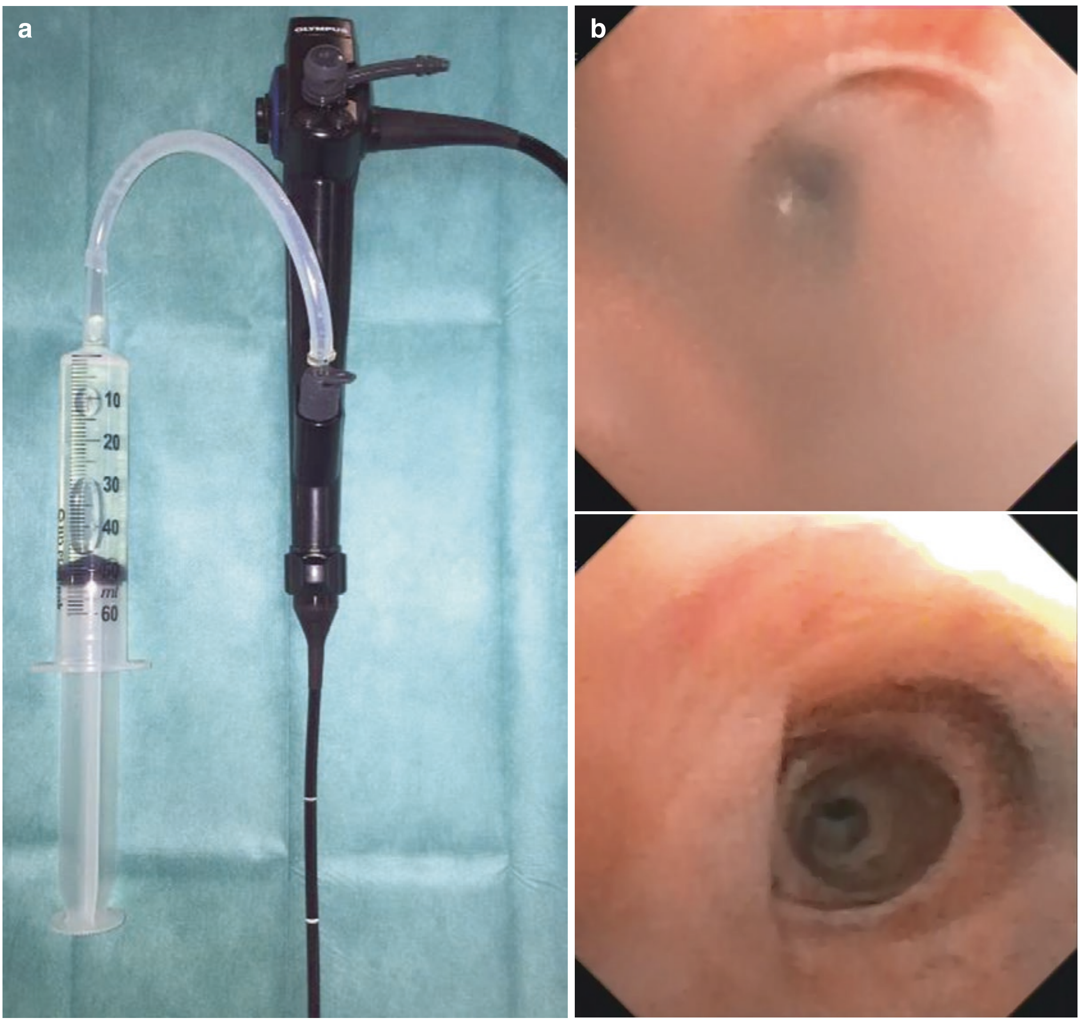

Fig. 3.8 Ultrathin bronchoscopy in peripheral airways: (**a**) 50 mL aliquot with saline connected to the working channel. (**b**) Views before and after saline infusion

This will guide the operator through the airways and assist in choosing the right direction in each encountered bifurcation. Therefore, when using a VBN system, two trained bronchoscopists will be needed: one to perform the virtual bronchoscopy and a second to advance the ultrathin the same path that the first is following. To date, there is only one large randomized trial comparing ultrathin bronchoscopy with and without the use of virtual bronchoscopic navigation. This study by Asano et al. showed no significant differences in diagnostic yield on both groups (67.1% vs. 59.9%, $p = 0.173$) in 350 patients with peripheral nodules ≤3 cm. However, subgroup analysis of these data showed that the navigation system could be helpful for achieving nodules located in the peripheral third of the lung, those invisible in the posteroanterior radiographs and when located in the upper right lobe. Fluoroscopy was used in both groups to ensure location of the ultrathin bronchoscope and sampling of the desired location [14]. At this point, several limitations encountered when performing ultrathin bronchoscopy need to be clarified.

The first concerns lung periphery. It is easy to understand that chances of getting lost in the peripheral third of the lung are greater since more bifurcations need to be overcome. The second concerns the probability of approximating a target that is not seen on plain chest X-ray. In fact, Kaneko et al. reported 73% negative chest radiography in 15 patients with CT-detected small peripheral lung cancers out of 1369 individuals at high risk screened for small peripheral lung cancer detection [15]. In these cases, only CT guidance will allow verifying that the ultrathin bronchoscope is approximating the nodule. The third critical consideration relies on the fact that only endobronchial nodules can be seen with a bronchoscope. A graphic explanation can be seen in Fig. 3.9, which shows Tsuboi's classification of the relationship between the nodule and the bronchus [16]. Therefore, achieving the target with a bronchoscope is sometimes simply impossible.

Finally, it has to be noted that width is not the only mechanical restriction to bronchoscopes but also angulation. This point becomes especially challenging in the upper lobes where the anatomical disposition of the airways may contain angulations that are challenging or even impossible to perform with the ultrathin bronchoscope. As commented before, by leaving the biopsy forceps inside the working channel, the instrument gains stiffness and avoids bending backward 180°.

Therefore, although virtual bronchoscopic navigation may be a useful image-based technique for aiding in ultrathin bronchoscopy performance in selected cases, sometimes this is simply not enough.

Verifying the Position of the Ultrathin Bronchoscope

When the peripheral pulmonary nodule has been approximated and if no endobronchial abnormality is visualized, fluoroscopy or CT can be used to verify the position of the ultrathin bronchoscope relative to the lesion. Fluoroscopy was the first imaging technique used for guiding the ultrathin bronchoscope to the nodule [2]. Biplanar fluoroscopy is desirable but, when not accessible, the C-arm must be rotated adequately. If the lesion is not fluoroscopically visible, the use of a VBN system is recommended. CT has also been used for verifying the position of the ultrathin bronchoscope [17, 18]. It allows for nodule detection independent of size, localization, and characteristics. However, in most centers it is not possible to perform bronchoscopy in the CT room, and it is also important to point out that irradiation is higher than with fluoroscopy.

Sampling with the Ultrathin Bronchoscope

Through the working channel, two instruments of 1 mm diameter can be used: mini cytology brush (Olympus BC-201C-1006) and reusable mini biopsy forceps (Olympus FB-56D-1). Caution must be taken to manipulate the forceps as they can break and their cost is relatively high (around 1000€).

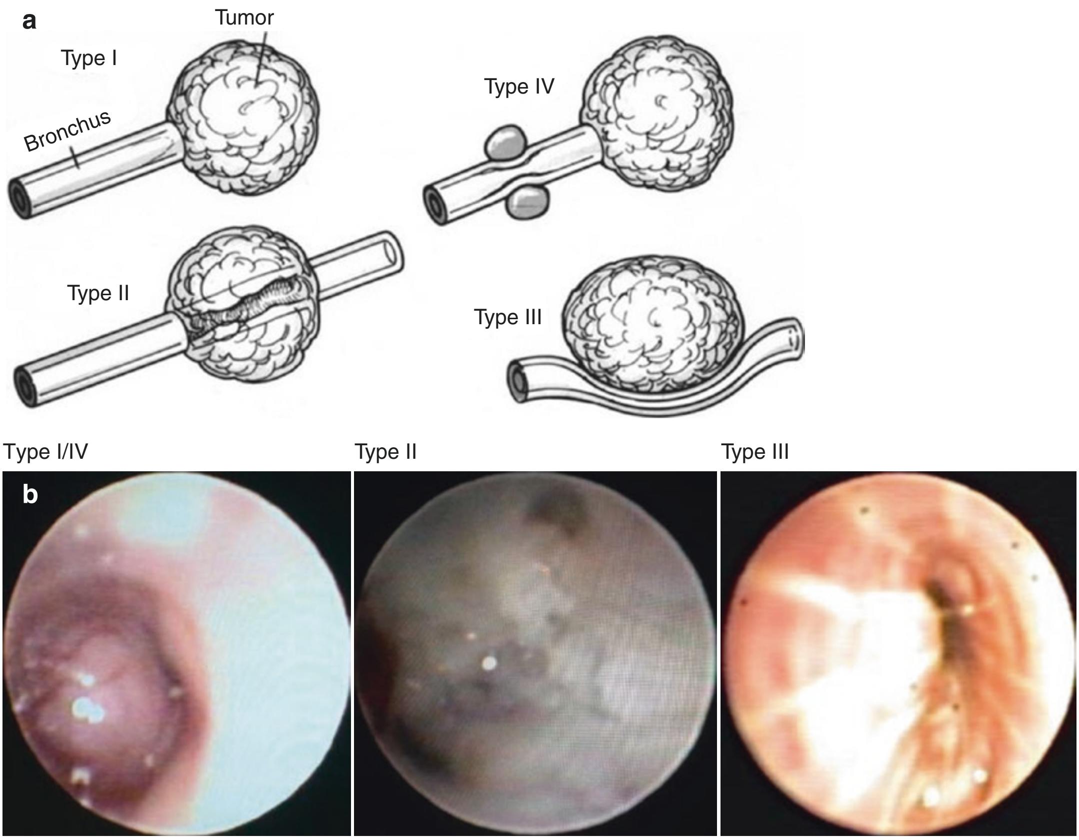

Fig. 3.9 (**a**) Tsuboi's classification of the relationship between the bronchus and the nodule. Type I: bronchus leads to the nodule. Type II: the bronchus is completely surrounded by the nodule. Type III: extrinsic compression without bronchial mucosal invasion. Type IV: the bronchus is proximally obstructed either by the peribronchiolar disease or by lymphadenopathy and then continues on to communicate with the tumor distally. Picture from reference [20]. (**b**) Examples of each type

Recent studies in animals have used mini cryoprobes that may allow for sampling of extrabronchial lesions and may therefore improve the quality and quantity of tissue obtained [19].

In the future, the development of thin needles for transbronchial needle aspiration (TBNA) would be desirable.

Once the peripheral nodule has been approximated, several points have to be considered:

1. Position of the lesion relative to the bronchus
   When an endobronchial lesion is reached (types I and II from Tsuboi's classification), sampling with forceps or brush under direct visualization is possible and rather simple. However, when there's only external compression or no alteration is directly visualized, even though the ultrathin bronchoscope has apparently reached the lesion after radiologic verification, the probability of obtaining a diagnosis diminishes significantly.

2. Sampling instruments are small
   This represents a major limitation in the era of molecular diagnosis. Therefore, it is important to take multiple samples with brushes and forceps. In our institution, four different biopsy and brushing samples are performed.

Complications

Although not frequent, several complications may occur during ultrathin bronchoscopy and these include:

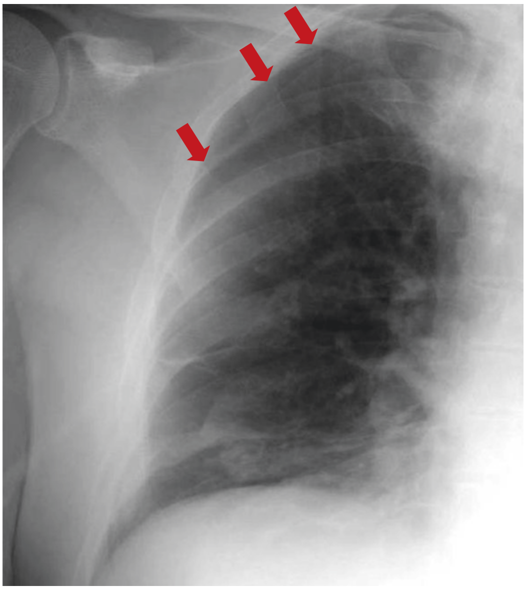

Fig. 3.10 Apical laminar pneumothorax after sampling a peripheral pulmonary nodule in the right lower lobe with an ultrathin bronchoscope

– Transient fever and pneumonia, especially if a relatively high amount of saline is retained and in those with purulent secretions. In our institution, prophylactic antibiotic with 2 g of amoxicillin/clavulanate is administered during the procedure.
– Pneumothorax can occur during or after sampling. Performance of a chest X-ray is recommended when biopsies are performed without endoscopic control. An example of a pneumothorax is seen in Fig. 3.10.

Summary and Recommendations

The ultrathin bronchoscope is a versatile instrument that is mainly used for studying peripheral pulmonary nodules but also for examination of cavitated nodules, critical stenosis, postoperative scars, barium marking prior to surgery, and giant bulla treatment.

When used for diagnosing a peripheral pulmonary lesion, it should be combined with image-guiding techniques in order to overcome the complex anatomy of the peripheral airways. Alone or in combination, these include (1) CT and/or virtual bronchoscopy for procedure planning; (2) fluoroscopy, CT, or virtual bronchoscopic navigation for orienting the bronchoscopist through the airways; and (3) fluoroscopy or CT for verifying the position of the ultrathin bronchoscope relative to the nodule, guiding the instruments during sampling and confirming that no pneumothorax has been produced right after sampling.

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